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EFFECTS OF WIND EROSION ON THE COMPOSITION AND FERTILITY OF SOME ALBERTA SOILS

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University of Alberta

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EFFECTS OF WIND EROSION ON THE COMPOSITION AND FERTILITY OF SOME ALBERTA SOILS

R. L. Erdman

INTRODUCTION

During the past several years, soil erosion by the wind has assumed alarming proportions, not only in Alberta, but also in Saskatchewan and Manitoba and in large areas of the semi-arid plains in the United States. It is not a new problem in Canada or the United States, for it has occurred periodically in the past. Soil drifting was recorded in western Canada as early as 1887 (23), but the first serious occurrence in Alberta was not reported until 1920 (17). At no previous time, however, has it assumed the sinister aspect with which it confronts the people of Canada and the United States at the present time. The governments of these countries, having awakened to the seriousness of the situation, have finally taken steps to combat this evil. In the United States, a Soil Erosion Service was established in 1933, and this department was enlarged in 1935, and renamed as the Soil Conservation Service, with wide powers to attempt to alleviate the grave situation existing in a large section of that country. In Canada, aside from conferences and recommendations, direct action was not taken until 1935, when

through the "Prairie Farm Rehabilitation Act", machinery was set in motion to study wind erosion and to check its devastations. In the same year, the province of Alberta passed its own "Control of Soil Drifting Act", coming into effect the following year, which subjected the occupier of the land to certain penalties for failure to use various control measures if wind erosion caused damage to adjacent lands (41). Further, the provincial government has placed 8 million acres of marginal and submarginal land in the drought and wind-erosion area under special government administration to avoid further damage in certain areas insofar as possible.

Causes of Wind Erosion. Wind erosion or soil drifting as it is commonly termed, is not limited to the bald prairie region in the southern and eastern portions of the province. It has been reported in the central parkland area, and even up to the Peace River district (45). It is therefore not peculiar to any soil zone or even soil type, although some soils are known to drift more readily than others (14, 44). The specific causes of soil drifting (41) have been listed as:

(1) Insufficiency of root fibre in the soil.

(2) Lack of cohesion between the soil particles themselves.

(3) High winds in conjunction with low precipitation.

(4) Tillage methods conducive to drifting or conducted at untimely periods.

In regard to the first point, it should be noted that fibre refers to the undecomposed plant residues and not to the humus content of the soil. The humus, or the decayed organic material appears to facilitate soil drifting (23), although it may have a binding effect on lighter soils (20). Other factors such as soil temperature and surface turbulence of the air currents appear to affect soil drifting also to some extent.

Effects of Wind Erosion. Wind erosion has affected over 16 per cent. of the total land area of the United States, or a total of 322 million acres (21). Of this figure, 9 million acres have been designated as "ruined", and another 80 million acres "badly damaged". It has been estimated that in the United States the direct toll of wind erosion is 400 million dollars annually (20).

In western Canada, of the total cultivated area, 26 per cent. is in fallow, much of which is susceptible to wind erosion. In 1934, 8½ million acres of cropped land were affected by drought and soil drifting, or 16 per cent. of the total cultivated area (23). The removal of one inch of top soil in the black soils of Alberta would indicate a replacement loss of between $200.00 and $300.00 per acre in considering only the nitrogen and phosphorus (45). This figure would range from $80.00 to $120.00 per acre in the brown and dark brown soils. This tremendous loss of the soil constituents is often overlooked, or not realized. After wind removal, the

subsurface soil may also be lower in plant nutrients and the physical condition may be changed. These phases are discussed in detail in later sections.

Besides the actual soil damage, there are various other results from wind erosion. Among these may be mentioned the injury to crops (which is often wrongly considered the most important loss), damage to shelter belts, fences, roadways, machinery, buildings, live stock and to the people themselves, resulting in physical ailments, and also demoralizing effects on their mental attitudes (see Plates IV and V). The necessity for combatting soil drifting by the use of various control and emergency measures (20,23,31,32,34,38,43,45) is quite apparent.

HISTORICAL

The effects of wind erosion in ancient times have received considerable study in late years. Dr. Reitz (33) in a very interesting manuscript, points out that nation after nation has fallen because of the exploitation and erosion of the soil. The mystery of why civilizations such as Persia, Assyria, Babylonia and Chaldea developed on lands now having a soil largely barren and desert, has thus been explained. It has also been noted by various authors (21,27,33) that according to the findings of archaeologists, large portions of the Sahara and Gobi deserts were once inhabited and teeming with

life. Similarly it is claimed that approximately 500 cities flourished in the present arid plains of Asia Minor. Similar devastation has occurred in Peru, the home of the oldest civilization on the western continent. Only from recent aerial photographs, can the shape and form of ancient walls, now entirely drifted over by sand, be recognized (27). Fears have been voiced from different quarters that unless some drastic measures are taken, a similar fate may be in store for the "dust bowl" of the United States, and for portions of western Canada (see Plate VI).

Although scientific data in regard to erosion of soils by water, are becoming quite voluminous, only a limited amount is available on the effects of wind erosion. The first report noted was by Ellis in 1920 (16), indicating the loss of organic matter caused by the wind in the soils of south western Manitoba. Various publications of a general nature (9,10,14,17,23,24,31,41,45) have been issued since. However, actual laboratory studies on the effects of wind erosion were not presented until 1935, when Moss (30) reported the results of investigations in Saskatchewan of the effects of wind erosion on the chemical and physical constituents of the soil. During the same year, Fly (18) issued a report on the chemical and mechanical analyses of dust deposited by the wind in Oklahoma. In 1936, additional results on the effects of wind erosion on the nitrogen and organic matter content of Oklahoma soils, were published by Daniel and Langham (13). Simultaneously another

paper was published by Daniel (12) reporting the physical changes in soils produced by the wind. Waksman (42) has presented a paper of a very recent date drawing attention to the detrimental effects which erosion may cause to the microbiological life of the soil, through the loss of organic matter. All of these technical papers, with the exception of the last one mentioned, are discussed in detail later under their respective sections.

METHODS AND MATERIAL

Methods. Total nitrogen, both in the soil and in the wheat was determined by the official Gunning-Hibbard method (4). The duplicates were checked to a difference of 0.009 per cent. of each other.

In regard to organic carbon, several methods were available. For reasonable accuracy, coupled with comparatively quick results, Schollenberger's chromic acid method, as modified by Allison (1,37) was employed. The soil sample was mixed with powdered potassium dichromate, concentrated sulphuric acid added, and then the mixture brought to 175°C. in 90 seconds. After cooling, it was diluted with distilled water, and titrated with ferrous ammonium sulphate, using diphenylamine as indicator. Duplicates were checked to a difference of 0.04 per cent. of each other.

Total organic matter was determined as the organic carbon multiplied by the generally recognized factor of 1.724.

Mechanical analyses were conducted on all the samples by the Bouyoucos' hydrometer method (5,6). This method has been shown to be quite accurate in comparison with the pipette method (8). The soil samples were first dispersed by sodium silicate and sodium oxalate. Hydrometer readings were recorded at given intervals and the percentages of the soil fractions were calculated from the records. The percentages of silt and clay were determined according to the new standards of the United States Bureau of Soils, effective January 1st, 1938 (3).

The pot experiment was carried out as described in a later section.

Total phosphorus and acid soluble phosphorus were determined on too few samples to warrant the results being recorded.

It should also be noted that all the chemical analyses were determined on air-dry weights, while the mechanical analyses were conducted on water-free soil samples.

Material. The soil samples used in this project were collected in various parts of Alberta during the fall of 1936, summer of 1937, and the samples from one profile in January, 1938. In all, 27 locations were sampled, resulting in 87 individual samples. At each location samples were taken of the normal (that is undrifted from all intents) cultivated

surface soil; the accumulated drift, and the exposed subsurface after wind removal. In addition to these, six dust samples were collected at two of these locations as indicated later in Table I.

In all cases composite samples were taken, being the aggregates of four or five smaller samples a few rods apart. Each group of samples, that is the normal soil, accumulated drift, and the exposed subsurface, was taken as close together as possible, and in all cases, excepting sample number 122, within 100 yards. All samples other than drift were from cultivated fields, except number 271, which was from virgin sod, as a normal cultivated sample of this particular type was not available in proximity. The samples of accumulated drift were collected from the depositions along fences or roadsides, and in a few cases from hummocks which formed in the field around stationary objects.

The samples of dust, that is numbers 134 to 137, 274 and 275, were collected at various heights from dwelling houses, vacant and occupied.

A complete list of the samples, together with their locations and descriptions is given in Table I. In each case, the sample numbers ending with the digit "1", refer to normal surface soil; in "2" to the accumulated drift, and in "3" to the exposed subsurface. Samples ending in digits above 3 refer to dust samples collected at different heights.

Table I. Location and description of samples

Sample No.	Location	Soil Type	Soil Zone	Degree of Drifting
11,12,13	29-13-23-4 Carmangay	Fine sand	Dark brown	Severe
21,22,23	23-13-23-4 Carmangay	" "	" "	"
231,232,233	29-13-23-4 Carmangay	" "	" "	"
271,272,273 (274,275 dust)	31-13-23-4 Carmangay	" "	" "	"
61,62,63	21-12-24-4 Barons	Fine sandy loam	Dark brown	Moderate
101,102,103	10-13-24-4 Barons	" " "	" "	"
241,242,243	24-12-24-4 Barons	" " "	" "	Severe
81,82,83	21-12-26-4 Claresholm	Loam	Dark brown	Moderate
91,92,93	10-13-26-4 Claresholm	"	" "	"
141,142,143	1-37-13-4 Fleet	"	" "	"
151,152,153	26-36-14-4 Castor	"	" "	"
161,162,163	25-37-9-4 Veteran	"	" "	Severe
211,212,213	36-3-25-4 Cardston	"	Southern black	Moderate
251,252,253	30-12-25-4 Claresholm	"	" "	"

Table I. (Continued)

Sample No.	Location	Soil Type	Soil Zone	Degree of Drifting
41,42,43	29-12-23-4 Barons	Silt loam	Dark brown	Moderate
51,52,53	17-12-23-4 Barons	" "	" "	Slight
111,112,113	5-13-23-4 Barons	" "	" "	Moderate
131,132,133, (134,135,136, 137 dust)	28-12-23-4 Barons	" "	" "	"
171,172,173	31-36-8-4 Veteran	" "	" "	Slight
191,192,193	31-4-28-4 Pincher Creek	" "	Southern black	Moderate
201,202,203	24-3-25-4 Cardston	" "	" "	"
221,222,223	16-3-25-4 Cardston	" "	" "	"
31,32,33	35-12-23-4 Barons	Clay loam	Dark brown	Moderate
71,72,73	2-12-25-4 Claresholm	" "	" "	"
261,262,263	34-11-25-4 Claresholm	" "	" "	"
121,122,123	33-12-23-4 Barons	Clay	Dark brown	Moderate
181,182,183	33-6-28-4 Brocket	"	" "	Severe

It should also be pointed out, as noted in Table I, that various degrees of drifting had occurred on the different soils. That is, the fine sands had in all cases been subjected to severe erosion. The intermediate types had drifted moderately, with a few exceptions. The clay loams also had eroded moderately, but in the clays one out of the two had exhibited severe erosion.

OUTLINE OF INVESTIGATION

In order to give the reader a better comprehension of what is to follow in the course of this study, a brief outline is given of the research conducted in this connection. These subdivisions are listed in the order they appear later in the discussion.

I. A brief study was conducted in regard to wind data for five points located in different sections of the province, and comparisons were made with wind observations from the "dust bowl" of Texas and Oklahoma.

II. A preliminary pot experiment was carried out to observe the response of growing plants to some normal and drifted soils.

III. Mechanical analyses were made of all the soil samples collected in order to ascertain the effect of wind erosion on the physical texture of the soil.

IV. Certain chemical analyses were conducted with the object of determining the effect of wind erosion on the soil fertility.

V. A limited study was made of the chemical and mechanical analyses of dust samples in comparison with the normal soil of the same vicinity.

RESULTS AND DISCUSSIONS

I. Wind Studies

In this section is included a brief examination of meteorological data respecting winds in various parts of Alberta, and at some points located in the wind-erosion area of the United States. This study was quite preliminary, and the results examined in most cases covered only a brief span of years. However, it was pointed out by Daniel (11), that there was only a slight change in wind velocity in the "Panhandle" of Oklahoma in the ten year period 1925 to 1934, which includes some of the years of severe wind erosion. In data submitted by Joel (25) for the twenty-five year period 1910 to 1934 in northern Texas the variability was somewhat greater. The surprising feature noted in these data was that although the mean annual velocity for the last two years recorded, that is the years of severe erosion, was slightly greater than for

several years preceding them, nevertheless it was just equal to the average of the mean annual velocities for the twenty-five year period. The precipitation figures for these same two years were just one half of the long term average. These facts seem to indicate that the amount of rainfall may be just as important as the wind in determining the degree of soil erosion.

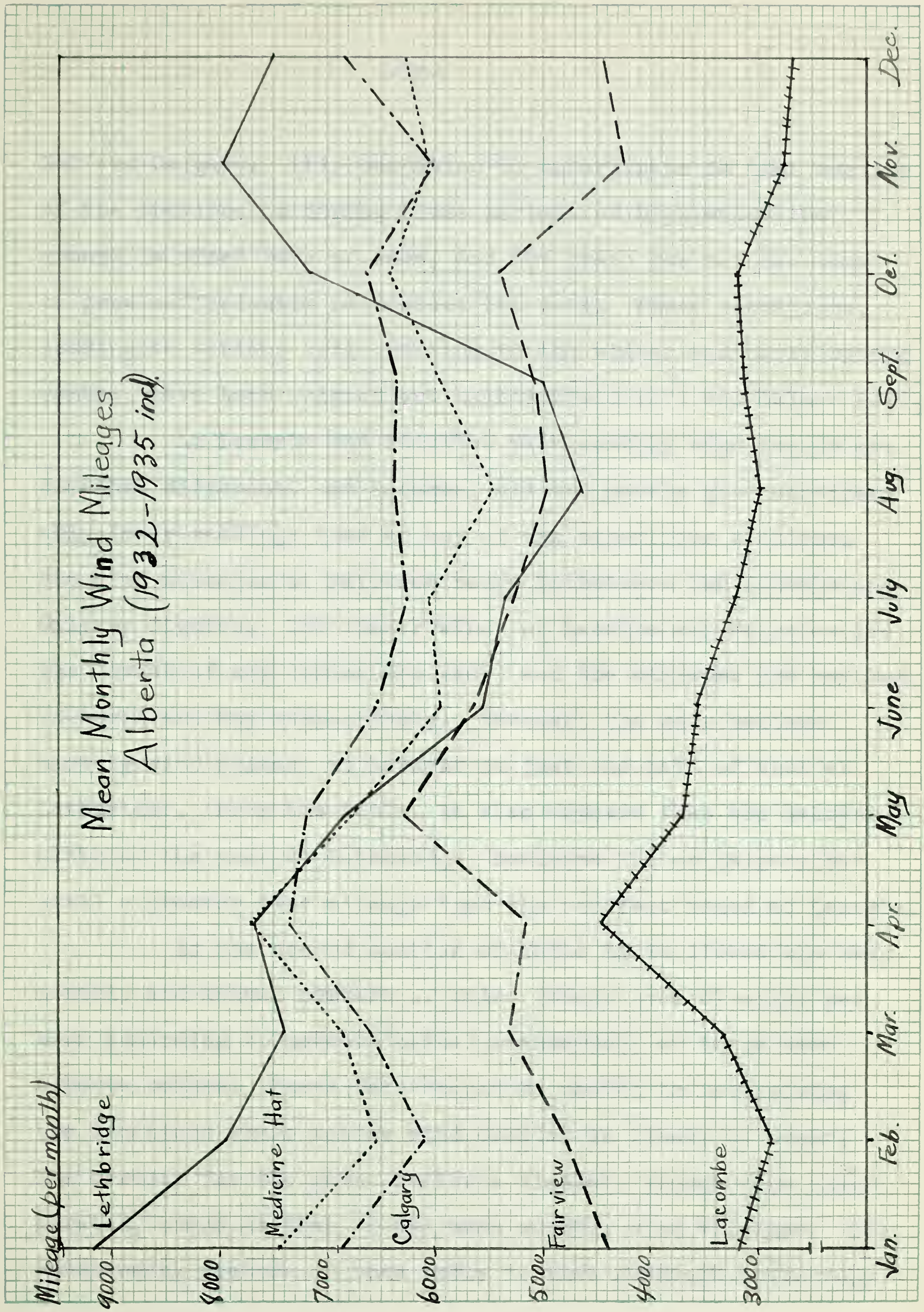
In Table II is presented the mean monthly and annual wind mileages and the numbers of gales during the years 1932 to 1935 (inclusive) for which data were available for a number of Alberta points (29). It might also be pointed out that the years under consideration were not all drought years or those of excessive drifting, as in 1932 reasonably good yields were obtained in southern Alberta when the wind mileage was considerably above that of 1933, when only one half the previous year's yield was realized (41). The points compared in this table are Lethbridge, Medicine Hat, Calgary, Lacombe and Fairview (Tp. 81, R. 3, W. 4), located in widely separated parts of the province. The figure appended illustrates diagrammatically the data from Table II.

In observing this figure it will be noted that Lethbridge has by a considerable margin, the highest mean monthly wind mileage of any point studied in the province. In that area, the greatest winds occur in the winter and the early spring months. A very similar trend is exhibited at Medicine

Table II. Mean monthly and annual wind mileages and numbers of gales: 1932-1935 inclusive (Alberta)

Location	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
						Wind Mileages							
Lethbridge	9,159	7,964	7,401	7,691	6,808	5,584	5,373	4,635	4,995	7,140	7,958	7,519	82,226
Medicine Hat	7,446	6,544	6,862	7,714	6,788	5,939	6,075	5,493	5,981	6,416	6,040	6,263	77,585
Calgary	6,882	6,094	6,605	7,393	7,202	6,582	6,237	6,380	6,351	6,611	6,027	6,816	79,228
Lacombe	3,158	2,883	3,317	4,487	3,702	3,538	3,226	2,993	3,118	3,183	2,787	2,656	39,045
Fairview	4,394	4,785	5,307	5,174	6,267	5,596	5,321	4,961	5,063	5,398	4,257	4,419	60,940
						Numbers of Gales#							
Lethbridge	5.3	4.8	2.5	2.8	0.5	0.3	0	0	0.3	2.3	2.8	2.5	24##
Medicine Hat	1.8	1.0	0.8	2.8	0.8	0.3	0.5	0.8	0.8	0	0.8	1.3	11
Calgary	0.8	1.0	2.0	2.8	0.5	0.5	0.5	0.5	0.5	0.8	0.3	2.8	13
Lacombe	0	0	0	0.5	0	0	0	0	0	0	0.3	0	1
Fairview	0.8	0.3	0.5	0.3	0.3	0	0	0	0.3	0.3	0.5	0.5	4

Gales considered as winds over 31 miles per hour.
##Computed to the nearest whole number.


Mean Monthly Wind Mileages
Alberta (1932-1935 incl.)
Mileage (per month)
9000
8000
7000
6000
5000
4000
3000
Lethbridge
Medicine Hat
Calgary
Fairview
Lacombe
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

Hat and Calgary. This condition is unfortunate in that section of the province as during these periods of high winds the ground is often bare of snow, and the grain has not had time to grow sufficiently to protect the soil. These conditions, leading to serious soil drifting in the winter and early spring months, have been pointed out by Fairfield (17) and Palmer (31).

At Lacombe and Fairview mean monthly wind trends are somewhat different. At Lacombe, all the months give considerably lower readings than at any of the other four stations. The wind mileages at Fairview range in between the Lacombe and Calgary figures. The winter winds at Lacombe and Fairview are the lowest of any during the year, and the maximums are reached in April and May respectively. However, the mean maximum monthly wind mileage at Lacombe is just one half of that at Lethbridge. From the table, it also appears that the calmest month of the year at Lethbridge, Medicine Hat or Calgary has still a greater wind mileage than the windiest month at Lacombe.

In the second section of Table II is listed the mean monthly and annual numbers of gales (winds over 31 miles per hour according to meteorological standards), at these same Alberta points. These data should be useful in determining the locations where severe wind erosion is likely to occur. The results for the gales follow a similar, though more exaggerated, trend as that of the mean monthly wind mileages. One outstanding feature of this table is that although Lethbridge

has a mean annual wind mileage (82,226 miles) only slightly higher than that of Medicine Hat (77,585) or Calgary (79,228), yet the number of gales, viz. 24, is double that at the other two points. This appears to indicate that the wind from the Crows Nest Pass is of a somewhat greater velocity and blows more in fits and starts in its initial stages, but steadies down as it extends further east. It is not surprising from the data on wind mileages that Lacombe has an average of only one gale, and Fairview four.

The number of gales occurring in a given locality is very important from the viewpoint of soil erosion, as under average conditions, a wind of 31 miles per hour may cause considerable drifting. However, various authors have submitted different velocities for soil-eroding winds. Johnson and Saunderson (26) in Montana give 21 miles per hour as the velocity of a soil-moving wind. Brandon and Kezer (10) in Colorado state that it requires a wind of 30 miles per hour to start soil erosion, but once started even a 12 mile wind will sustain it. Joel (25) however considers a soil-eroding wind as one blowing 35 miles per hour. Staple and Chepil (40) at the Soil Research Laboratory, Swift Current, found in an actual test under a given set of conditions, that drifting occurred with a wind of 15.7 miles per hour, but not at 14.2 miles per hour. However, these readings were taken at a 10 inch height and they point out that velocities are somewhat higher even

at 30 inches. It was also noted (40) that the velocity of a soil-moving wind depends on the temperature and surface turbulence of the air, besides on the soil factor itself.

In Table III a comparison is made of certain specific wind data from points in Alberta, Oklahoma and Texas. One surprising feature is that the mean annual wind mileages for Goodwell, Oklahoma (11), and for Dalhart, Texas (25), located in the so-called "dust bowl", are considerably lower than for Southern Alberta. It is also very interesting to note that Lacombe has 52.5 per cent. less wind than Lethbridge, while Medicine Hat and Calgary are only slightly lower. The numbers of gales were not available for the locations in Oklahoma and Texas.

Figures were also scrutinized for the maximum wind mileages in 24 hours for the five Alberta points during the same period. Lethbridge again was the highest, with 808 miles in 24 hours (January, 1934), or an average of 33.7 miles per hour during the whole period. Calgary followed close with 781 miles in 24 hours (April, 1933), or an average velocity of 32.5 miles per hour. At Medicine Hat, 682 miles (February, 1932), was the maximum recorded, equaling 28.4 miles per hour. Fairview and Lacombe were considerably lower totalling 568 (May, 1932) and 457 (April, 1933) miles in 24 hours, or 23.6 and 19.0 miles in one hour respectively. Such continuous high winds as recorded at Lethbridge, Calgary and Medicine Hat would

undoubtedly cause serious erosion on fields which were at all predisposed to drifting.

Table III. Comparison of wind data from Alberta, Texas and Oklahoma

Location	Mean annual wind mileages; 1932-1935	Mean miles per hour	Variation from Lethbridge %	Mean annual number of gales[x]
Lethbridge	82,226	9.38	---	24
Medicine Hat	77,585	8.67	-7.6	11
Calgary	79,228	9.04	-3.7	13
Lacombe	39,045	4.46	-52.5	1
Fairview	60,940	6.95	-25.9	4
Goodwell,# (Oklahoma)	69,379	7.92	-15.6	--
Dalhart,## (Texas)	60,092	6.70	-28.6	--

[x] Gales considered as winds over 31 miles per hour.
#Averages for 1925 to 1934.
##Averages for 1910 to 1934.

Another brief survey was conducted in regard to the prevailing wind directions. Geib (19) states that in the Panhandle of Oklahoma only 32 per cent. of the wind blew from one direction and that damaging winds occurred from any point of the compass. However, it was computed from the data available that at Lethbridge 79 per cent. of the prevailing winds were from the southwest. At Medicine Hat 81 per cent blew from this same direction. However, at Calgary the situation had changed, with 48 per cent. of the prevailing winds from

the northwest, and 46 per cent. from the north. Lacombe exhibited still greater variability, 31 per cent. of the prevailing winds being from the south, 23 per cent. from the west, and 17 per cent. from the southwest. Fairview was somewhat similar with 35 per cent. from the southwest and 29 per cent. from the west. These prevailing wind directions are quite important in determining the direction of strips as used in strip farming practices for the control of soil drifting.

In concluding this section on wind studies, several important points were noted. Conclusions should not be drawn from four year averages, but the winds, at any one location appear to be quite stable from year to year, although the seasonal variation may be considerable. The figures submitted indicate that the wind in the southern and eastern section of Alberta is double that in the central section, with that at Fairview intermediate to these locations. Also it was noted that the wind at two points of the "dust bowl" of the United States was considerably lower than in southern Alberta. Figures on the numbers of gales indicated that at Lethbridge twice the number occurred as at any of the other points in the province. A study of prevailing directions indicated that the winds in southern Alberta were consistently from the westward direction, while they were quite variable at Lacombe and Fairview.

II. Pot Experiment

This experiment was arranged merely as a preliminary study in order to observe how growing plants responded to eroded and non-eroded soils, under a similar set of conditions. The results cannot be considered as conclusive, due to the limited scope of the experiment. However, some interesting observations were noted. Such an experiment, under controlled environmental conditions, should be more reliable than ordinary field results. In the latter case, differences in crop growth may be caused by varying moisture conditions, tilth, aeration, or other physical factors which can be largely overcome in a pot experiment in a greenhouse.

In Table IV is recorded the mechanical and chemical analyses of the soils used in the pot experiment. It will be noted that the three categories of four different soil types were used, that is the normal cultivated surface, accumulated drift, and exposed subsurface samples of fine sand (Carmangay), silt loam (Barons), loam (Claresholm), and clay (Barons). The soil sample numbers are also recorded so that a more detailed description and location of the samples can be obtained by reference to Table I. However, it might be pointed out here that the fine sand had been subjected to severe erosion while the other three soil types had drifted only moderately. Also it might be noted that the individual soil samples were tested

Table IV. Mechanical and chemical analyses of soils used in pot experiment

Pot Number	Soil Sample Number	Type of Soil	Location	Sand %	Silt %	Clay %	Nitrogen %	Organic Matter %
1 2	11	Fine sand	Normal surf.	75.5	16.3	8.2	.099	1.84
3 4	12	" "	Acc. drift	86.6	9.0	4.4	.041	0.74
5 6	13	" "	Exp. sub.	86.0	5.4	8.6	.030	0.60
7 8	41	Silt loam	Normal surf.	39.5	44.5	16.0	.208	3.69
9 10	42	" "	Acc. drift	41.0	47.4	11.6	.210	3.71
11 12	43	" "	Exp. sub.	36.0	42.4	21.6	.199	3.10
13 14	81	Loam	Normal surf.	53.0	35.0	12.0	.185	3.60
15 16	82	"	Acc. drift	52.5	34.3	13.2	.223	4.65
17 18	83	"	Exp. sub.	54.0	34.8	11.2	.176	3.83
19 20	121	Clay	Normal surf.	22.5	43.5	34.0	.447	8.98
21 22	122	"	Acc. drift	23.0	42.6	34.4	.483	9.40
23 24	123	"	Exp. sub.	18.0	44.4	37.6	.365	7.17

just in duplicate, due to insufficiency of samples for any greater replication.

By reference to Table IV, it is observed that the mechanical analyses of the soils vary considerably in some cases, and very little, if any, in others. In regard to the fine sand, it is noted that the accumulated drift has increased considerably in the sand fraction, and also has lost nearly half its silt and clay, as compared to the normal sample. The exposed subsurface has deteriorated similarly, containing even less silt, but more clay. In the silt loam, the physical differences between the normal and the accumulated drift are practically insignificant. The exposed subsurface sample is, however, slightly lower in sand and higher in clay. In the loam samples, no variation is present in any of the three classes or categories. The normal and drift of the clay soil are also identical, but the subsurface is somewhat lower in sand and higher in the clay fraction.

In considering the chemical analyses, it is observed from the table that the fine sand exhibits very striking differences. The accumulated drift in this case has lost nearly 60 per cent. and the exposed subsurface 70 per cent. of the nitrogen present in the normal cultivated surface soil. Similar differences are disclosed in the organic matter contents of these samples. In respect to the silt loam, differences in nitrogen and organic matter of the normal and the accumulated

drift are negligible. There is however a slight decrease in nitrogen, and a somewhat greater loss in organic matter of the exposed subsurface as compared to the normal soil. The significant feature of the loam soil is the higher percentage of nitrogen and organic matter in the drift sample. The subsurface is practically identical to the surface. In the clay samples there is a significant difference between the accumulated drift and the exposed subsurface. The former is somewhat higher in nitrogen and organic matter than the normal, and the latter is materially lower in both of these constituents.

Procedure. The individual samples of soil were thoroughly mixed and transferred into duplicate 6 inch clay pots. In all cases 1750 grams (approximately 4 pounds) of air dry soil were used. Moisture conditions were brought to the optimum by adding 15 per cent. by weight, of water to the fine sand, 20 per cent. to the loam, 25 per cent. to the silt loam and 30 per cent. to the clay samples. Then the total weight of each pot was recorded and the pots were maintained at these figures by the addition of water every second or third day. On October 8, 1937, the 24 pots were seeded to wheat, Reward variety being used in preference to Marquis in order to hasten maturity. Five kernels were seeded to each pot, then thinned to four plants on October 22, and to three to avoid overcrowding on November 2. All the pots were kept in the Soils' greenhouse until November 4, and then, through the

courtesy of the Field Crops Department, they were transferred to the latter's greenhouse, where artificial lighting was available to stimulate growth. The temperatures in both cases ranged from 50 to 75°F. averaging close to 65°F.

Results and Discussion. The first shoots to appear were in the fine sand on October 15, seven days after planting. However no general trend was noticeable in each soil type except on the clay soils. In this case, the samples on the exposed subsurface were the last to emerge, namely on October 19, or eleven days after seeding.

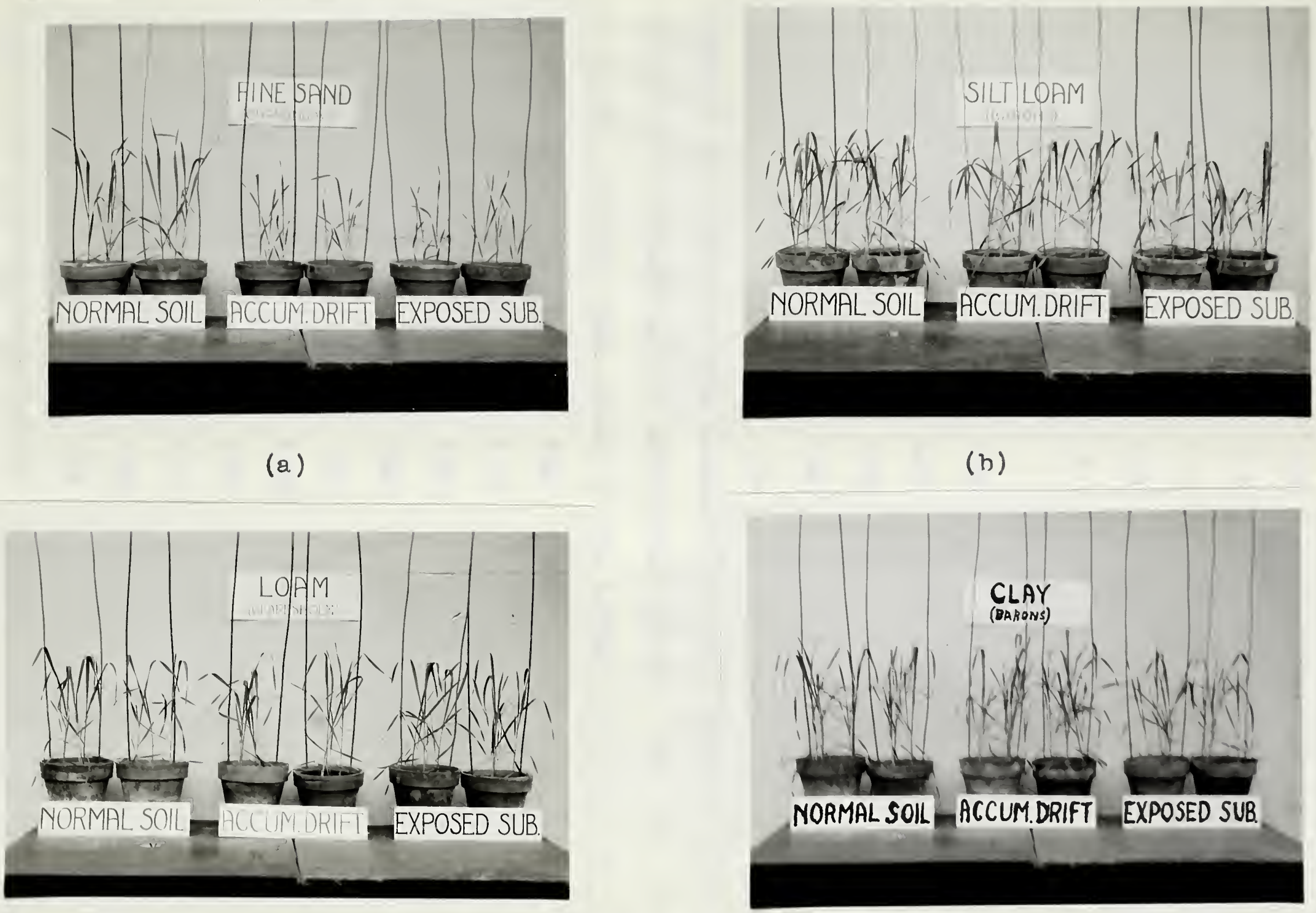
The wheat on the fine sand made the most rapid growth at first and by October 29, just three weeks after planting, differences were noticeable between the sand samples themselves. That is the plants in the accumulated drift and the exposed subsurface soils showed signs of lagging behind those in the normal fine sand. No significant variations were discernible in the other three soil types.

In Plate I is illustrated the pot experiment as it had progressed by November 18, when the photographs were taken. Each group of six pots is arranged in a similar manner, that is the first two pots contain normal surface soil, the middle two accumulated drift, and the final two exposed subsurface samples. In observing (a), that is the pots containing fine sand, it is noted that the plants in the normal soil are distinctly superior to any of the others in this group. The

accumulated drift and the exposed subsurface samples have had at this stage, an equally retarding influence on the plants. Also it was recorded that the color of the plants on these soils was somewhat paler and chlorotic as compared to the wheat on the normal fine sand.

In observing (b), (c) and (d) in Plate I, no significant differences can be noted between the various pots on the silt loam, loam and clay soils respectively.

On December 10, 1937, the first heads appeared, namely one on each of the three classes of fine sand and two in one of the normal loam pots. The following day a second head emerged on one of the normal fine sands. By December 12, the third day since heading commenced, spikes were present on the plants in all categories of the four soil types except on the exposed subsurface of the silt loam, and on the accumulated drift and exposed subsurface of the clay. By December 14, heads had formed on all the soil types and classes. The tendency in time of heading therefore appeared to be a slight delay on the exposed subsurfaces of the silt loam and of the clay. It should also be recorded that although heads formed simultaneously on all of the fine sand pots, those spikes on the accumulated drift and on the exposed subsurface samples were considerably smaller than those on the normal soil. No differences in size were recorded on any of the other soil types.



(a) (b)

(c) (d)

Plate I. Pot Experiment at 6 Weeks.

In Plate II is presented illustrations of the plants as they appeared on December 23, that is on the fourteenth day after heading commenced. It was considered at the time that heading was completed, but additional spikes continue to appear on the normal silt and on all the clay soils until January 21, 1938.

In checking over the (a) figure in Plate II, some striking differences are observed. The tendencies appearing on the corresponding print taken a month earlier are at this stage considerably accentuated. The plants on the normal fine sand are well-developed with reasonably good-sized heads. However the plants on the accumulated drift samples give indications of dwarfing and under-nourishment. They are about 12 inches shorter than those on the normal soil and the heads are approximately one half the size. The plants on the exposed subsurface samples are still less developed. Their maximum height is only 20 inches (allowing 6 inches for the pot), just one half of those in the normal soil. The heads are still further reduced than on the accumulated drift samples. On the whole these results indicate that wind erosion has rendered very serious damage to the productivity of this soil, the exposed subsurface apparently being more deficient in available plant nutrients than the accumulated drift.

In checking over (b), (c) and (d) in Plate II no significant differences can be observed from the prints. All the plants in these 18 pots are well developed, and the

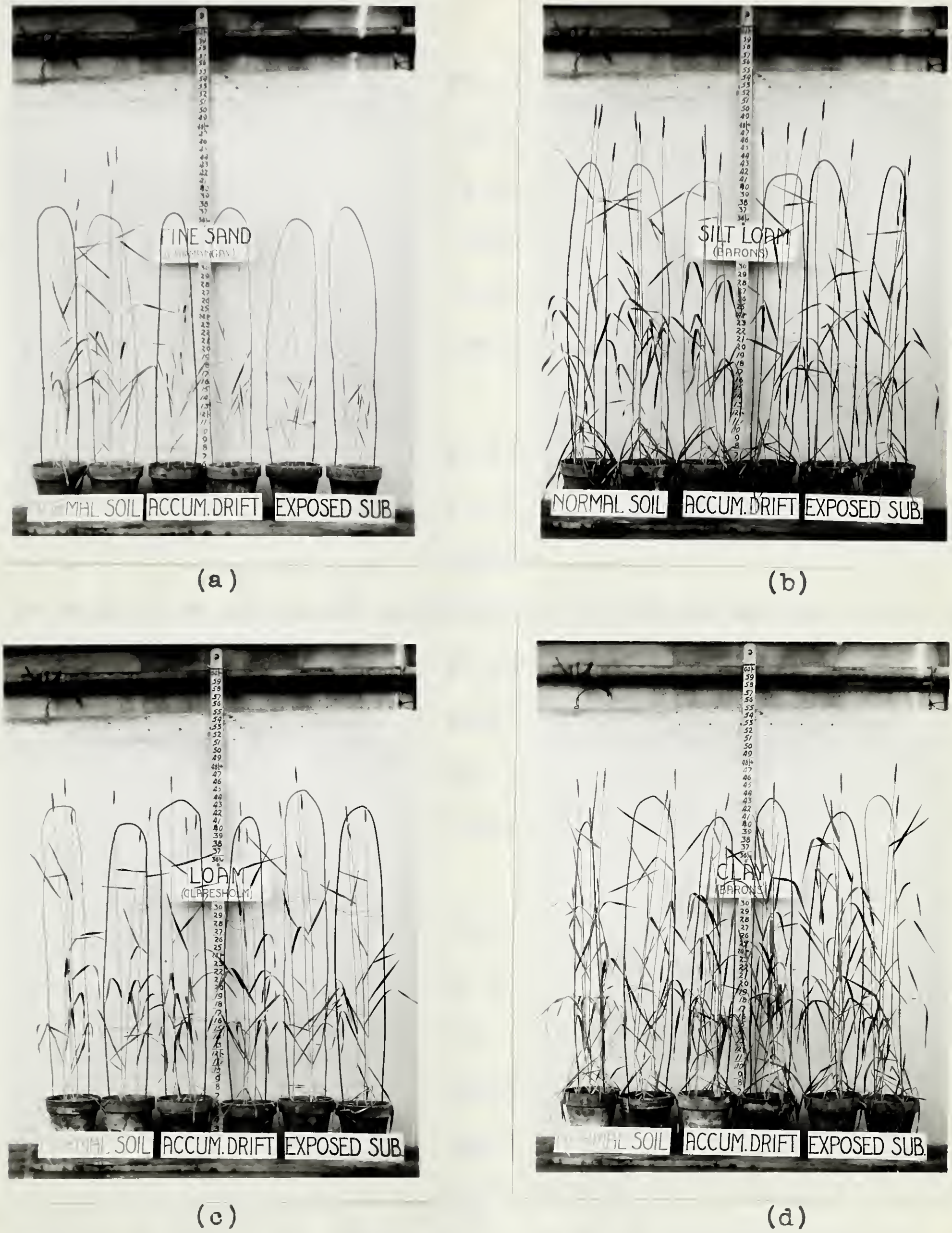


Plate II. Pot Experiment at 11 Weeks

differences between duplicates, in some cases are greater than between the three categories of the respective soil types. Wind erosion therefore has not caused any visible damage to these soils up to this stage insofar as plant growth is concerned. There was, however, a minor difference in the numbers of heads which was further accentuated at the conclusion of the experiment.

This preliminary pot experiment came to an abrupt end on January 21, 1938, when some of the plants in four of the pots were damaged by a rodent. It had been hoped to mature the wheat and determine differences in the weight of grain, but under the circumstances it was deemed best to use the total weight of the plants as the standard. Furthermore seed-setting had not fulfilled expectations, whether due to light conditions in midwinter, artificial lighting used, or to soil factors, was difficult to determine.

The plants were consequently clipped off on January 22, 1938, and the total weight from each pot recorded at the time of cutting. As the plants had only advanced to the soft dough stage, they were thoroughly dried and the air dry weights also recorded. In addition the numbers of heads, total and fertile, was noted. As another point of interest the duplicate samples of the whole plant were ground up together and the nitrogen content determined.

In Table V is presented the complete data on the final results of the pot experiment, together with the nitrogen

Table V. Total weights, numbers of heads and per cent. nitrogen in wheat plants in pot experiment

Pot No.	Soil Type and Location	Weights of Wheat Plants				No. of Heads		[#]Nitrogen %	
		Green	Ave.	Air dry	Ave.	Total	Fertile	In Plants	In Soil
1	F. Sand - normal	7.5	8.0	3.2	3.4	3	2	1.32	.099
2	" "	8.5		3.5		3	2		
3	" acc. drift	3.5	3.0	1.5	1.4	3	0	1.64	.041
4	" " "	2.5		1.2		3	0		
5	" exp. sub.	1.3	1.3	0.8	0.7	3	0	1.49	.030
6	" " "	1.2		0.6		3	0		
7	Si.Loam - normal	22.0	21.3	7.5	7.2	4	3	1.60	.208
8	" "	20.5		6.9		5	3		
9	" acc. drift	19.5	18.8	6.7	6.3	3	3	1.57	.210
10	" " "	18.0		5.8		3	3		
11	" exp. sub.	11.5	12.5	4.0	4.4	3	3	1.36	.199
12	" " "	13.5		4.8		3	3		
13	Loam - normal	12.5	12.3	4.2	3.9	3	3	1.80	.185
14	" "	12.0		3.5		3	2		
15	" acc. drift	12.0	11.8	3.9	4.0	3	2	1.62	.223
16	" " "	11.5		4.0		3	3		
17	" exp. sub.	13.0	11.8	4.2	3.8	3	2	1.57	.176
18	" " "	10.5		3.4		3	1[##]		
19	Clay - normal	28.0	26.8	8.7	7.9	7	3[x]	1.77	.447
20	" "	25.5		7.1		6	3		
21	" acc. drift	37.5	36.3	10.0	9.9	8	4[x]	1.99	.483
22	" " "	35.0		9.7		9	3		
23	" exp. sub.	30.5	28.0	8.6	8.1	7	3[x]	1.81	.365
24	" " "	25.5		7.6		7	2		

[#] Nitrogen content of plants checked to a difference of 0.02 per cent. except in sands where there was insufficient sample for repeats. Nitrogen content of soils checked to 0.009.

[##] In this case two unclassified heads were removed by a rodent.

[x] In this case one unclassified head was removed by a rodent.

content of the corresponding soils listed in the last column at the right. From these data, some interesting points are observed. Firstly, there is generally good agreement between the different sets of duplicates both in regard to the weights of plants produced, and in the numbers of heads formed. In regard to the fine sand, very striking differences occur in total weights. The average air dry weight of the plants on the accumulated drift is less than one half of that on the normal soil, and those on the exposed subsurface are less than on quarter. The results of the silt loam soils follow the same trend, but the differences are minor, particularly between the weights of the plants on the accumulated drift and the normal soils. In regard to the loam soil, the plants grown were practically identical in weights in all cases. On the clay soils, the plants on the exposed subsurface equalled those on the normal, but those produced on the accumulated drift were 25 per cent. higher in total weight.

Another interesting feature recorded in this table is the number of heads produced. The normal fine sand produced a total of three heads in each pot, of which two in each case were observed to be fertile. On the drift samples, three considerably smaller heads were produced in each pot, but not one was fertile. In the pots containing the exposed subsurface soil, three heads still more dwarfed in size were formed, but none of these had developed any kernels. This sterility in the

grain may have been influenced by seasonal, or light factors, but it also has been noted by Griffiths (20) that on badly eroded soils sterility of cereals may be prevalent.

In regard to the silt loam samples, four heads on one and five on the other normal sample were produced, with only three each on the accumulated drift and exposed subsurface samples. However, in observing the spikes for the presence of kernels, it was found that in each case just three of the heads were fertile.

In considering the loam soils, each of the duplicates in the three categories produced just three heads. In respect to their fertility no differences could be determined. The numbers of heads bearing grain on the normal and drift were identical, and on the exposed subsurface, two unclassified heads had been removed by a rodent, thereby leaving this point in doubt.

On the clay soils the numbers of heads which finally formed were considerably higher than on any of the other soil types, the clay itself being very materially higher in total nitrogen. On the normal clay, there were six heads in one and seven in the other duplicate. On the accumulated drift sample, there were eight and nine, while the exposed subsurface samples yielded seven spikes each. In regard to their fertility, there were three heads bearing kernels on each of the normal samples, three and four on the drift and two and three on the exposed subsurface samples.

The results for the nitrogen content of the total plant are somewhat conflicting, although they do correspond to the data on the number of fertile heads except for the fine sand. In this case the per cent. nitrogen in the plants was higher in those produced on the drift and subsurface samples than on the normal soil, which was the only one giving rise to fertile heads. This peculiarity can be reconciled by the fact that the proportion of leaves to the total plant was considerably higher in the dwarfed specimens on the eroded soils, than in those on the normal soil. In regard to the silt loams, the nitrogen content of the plants was the same for those from the normal and drift soils, but was somewhat lower for the wheat plants grown on the exposed subsurface. On the loam soils, the nitrogen content was greatest for the plants on the normal soil, with that in the plants from the drift and subsurface slightly lower and practically equal to each other. The clay soils, in spite of their rank growths, also had the highest nitrogen content in the crop produced. In this case, the plants on the accumulated drift were somewhat higher in nitrogen than those on the normal or subsurface soil samples. In comparing the nitrogen content of the soils, as recorded in the last column, with that of the plants, there is a tendency for the two to correspond, with the exception of the fine sand. There is, however, a better agreement between the nitrogen contents of the normal and eroded soils in all cases, and the total weights of the plants produced.

In concluding this section on the pot experiment, some interesting points were observed namely:

(1) The effect of wind erosion on fine sand soil samples was noted on plant development as early as three weeks after seeding. These differences were accentuated in later stages, as indicated by the illustrations.

(2) Silt loam, loam, and clay soils, subjected to moderate drifting, did not have any visible effect on plant growth at 2½ months after seeding.

(3) Significant differences in the total weights of the plants were noted 3½ months after planting, in all the eroded soils except on the loam samples.

(4) Minor, though probably significant differences were noted in the numbers of heads formed, total and fertile, on all except the loam soil.

(5) Differences in the nitrogen content of the plants tended to follow that of the soils on all except the fine sand samples.

These results indicate on the whole that the fine sand soil type was seriously damaged by wind erosion, insofar as actual crop production is concerned, only minor injury was incurred to the silt loam, and little effect on plant development was noted in the loam and clay samples used.

III. Mechanical Analyses

Mechanical analyses were conducted on all of the normal, accumulated drift and exposed subsurface samples by the method as previously outlined, to determine the effects of wind erosion on the physical composition of the soil. It must be remembered, however, that a mere comparison of the varying percentages of the soil fractions does not present a complete picture of the situation. According to Bradfield (9), wind or water erosion, by removing a portion of the top soil and organic matter, may destroy the natural soil aggregates, leaving an impervious, deflocculated surface, even though the change in the actual percentages of the various soil fractions may have been relatively slight. Such a physical environment reduces microbiological activity (42), and in consequence the supply of available plant nutrients is decreased. We thus see that the physical environment may be just as important as the chemical composition of the soil in relation to crop production.

It is generally conceded that a medium-textured soil is preferable to a light or heavy one for ordinary crop production. That is, a soil of the loam or silt loam type is more friable and easier to work than a heavy soil, has a better moisture-holding capacity than a light soil and absorbs it more readily than a heavy one. Such an ideal soil is one which contains a considerable amount of silt with reasonable

percentages of sand and clay. We shall note later how wind erosion has affected this ideal balance of the various soil fractions.

Results and Discussion. In Table VI is recorded the mechanical analyses of the individual normal and eroded soils. For convenience, and purposes of comparison the soils are arranged according to type. The soils are compared under three general classes, that is the coarse-textured soils, including the fine sands and fine sandy loams; the medium-textured soils or loams and silt loams; and the fine-textured soils, including the clay loams and clays. Further, in Table VII is presented the average mechanical composition of the soils in these three classes. It might also be noted here that although the clay ratio was suggested by Bouyoucos (7) as a criterion of the susceptibility of soils to erosion, it was found by Daniel (12) to have very little relation to wind erosion. It was consequently not determined by the writer.

In considering the data in Tables VI and VII, in regard to the fine sands and fine sandy loams, we find a consistent increase in the sand content of the accumulated drifts, ranging from 12.1 per cent. to 48.1 per cent. with the average 18.9 per cent. Similarly there is a consistent and very considerable decrease in the silt content of the drift, ranging from 20.6 per cent. to 80.0 per cent., averaging 55.8 per cent. Further the clay content also has been reduced very

Table VI. Mechanical analyses of some normal and eroded Alberta soils

		Sand		Silt		Clay	
Sample No.	Kind of Soil	Per Cent.	Diff. %	Per Cent.	Diff. %	Per Cent.	Diff. %
		Fine Sands					
11	Normal	75.5	--	16.3	--	8.2	--
12	Acc. drift	86.6	+14.7	9.0	-44.8	4.4	-46.3
13	Exp. sub.	86.0	+13.9	5.4	-66.9	8.6	+ 4.9
21	Normal	78.0	--	15.4	--	6.6	--
22	Acc. drift	87.4	+12.1	7.4	-51.9	5.2	-21.2
23	Exp. sub.	80.0	+ 2.6	11.6	-24.7	8.4	+27.3
231	Normal	79.5	--	15.7	--	4.8	--
232	Acc. drift	89.6	+12.7	6.4	-59.2	4.0	-16.7
233	Exp. sub.	83.8	+ 5.4	11.8	-24.8	4.4	- 8.3
271	Normal	73.5	--	19.7	--	6.8	--
272	Acc. drift	85.8	+16.7	9.4	-52.3	4.8	-29.4
273	Exp. sub.	72.0	- 2.0	21.6	+ 9.6	6.4	- 5.9
		Fine Sandy Loams					
61	Normal	68.0	--	20.4	--	11.6	--
62	Acc. drift	77.0	+13.2	16.2	-20.6	6.8	-41.4
63	Exp. sub.	62.2	- 8.5	24.2	+18.6	13.6	+17.2
101	Normal	59.0	--	31.0	--	10.0	--
102	Acc. drift	87.4	+48.1	6.2	-80.0	6.4	-36.0
103	Exp. sub.	71.5	+21.2	19.7	-36.5	8.8	-12.0
241	Normal	72.5	--	21.1	--	6.4	--
242	Acc. drift	88.0	+21.4	7.2	-65.9	4.8	-25.0
243	Exp. sub.	75.0	+ 3.4	18.2	-13.7	6.8	+ 6.3

Table VI. (Continued)

		Sand		Silt		Clay	
Sample No.	Kind of Soil	Per Cent.	Diff. %	Per Cent.	Diff. %	Per Cent.	Diff. %
		Loams					
81	Normal	53.0	--	35.0	--	12.0	--
82	Acc. drift	52.5	- 0.9	34.3	- 2.0	13.2	+10.0
83	Exp. sub.	54.0	+ 1.9	34.8	- 0.6	11.2	- 6.7
91	Normal	58.4	--	32.0	--	9.6	--
92	Acc. drift	68.0	+16.4	23.2	-27.5	8.8	- 8.3
93	Exp. sub.	53.6	- 8.2	34.0	+ 6.3	12.4	+29.2
141	Normal	52.0	--	40.0	--	8.0	--
142	Acc. drift	67.5	+29.8	24.9	-37.8	7.6	- 5.0
143	Exp. sub.	55.4	+ 6.5	36.6	- 8.5	8.0	0
151	Normal	60.0	--	33.6	--	6.4	--
152	Acc. drift	79.0	+31.7	15.0	-55.4	6.0	- 6.3
153	Exp. sub.	69.0	+15.0	23.0	-31.6	8.0	+25.0
161	Normal	59.5	--	31.3	--	9.2	--
162	Acc. drift	88.2	+48.3	5.8	-81.5	6.0	-30.4
163	Exp. sub.	69.0	+16.0	23.8	-24.0	7.2	-21.7
211	Normal	54.0	--	34.4	--	11.6	--
212	Acc. drift	69.5	+28.4	20.5	-39.3	10.0	-13.8
213	Exp. sub.	60.0	+11.1	29.6	-14.0	10.4	-10.4
251	Normal	49.5	--	40.1	--	10.4	--
252	Acc. drift	54.2	+ 9.5	36.6	- 8.7	9.2	-11.5
253	Exp. sub.	49.0	- 1.0	41.8	+ 4.2	9.2	-11.5

Table VI. (Continued)

		Sand		Silt		Clay	
Sample No.	Kind of Soil	Per Cent.	Diff. %	Per Cent.	Diff. %	Per Cent.	Diff. %
		Silt Loams					
41	Normal	39.5	--	44.5	--	16.0	--
42	Acc. drift	41.0	+ 3.8	47.4	+ 6.5	11.6	-27.5
43	Exp. sub.	36.0	- 8.8	42.4	- 4.7	21.6	+28.8
51	Normal	42.5	--	47.5	--	10.0	--
52	Acc. drift	43.0	+ 1.2	42.2	-11.2	14.8	+48.0
53	Exp. sub.	42.0	- 1.2	44.4	- 6.6	13.6	+36.0
111	Normal	41.0	--	41.8	--	17.2	--
112	Acc. drift	35.0	-14.6	46.6	+11.5	18.4	+ 7.0
113	Exp. sub.	28.5	-30.5	47.9	+14.6	23.6	+37.2
131	Normal	52.0	--	35.6	--	12.4	--
132	Acc. drift	64.2	+23.5	24.6	-30.9	11.2	- 9.7
133	Exp. sub.	50.5	- 2.9	34.7	- 2.5	14.8	+19.4
171	Normal	48.5	--	39.5	--	12.0	--
172	Acc. drift	57.5	+18.6	34.5	-12.7	8.0	-33.3
173	Exp. sub.	45.5	- 6.2	42.1	+ 6.6	12.4	+ 3.3
191	Normal	42.0	--	43.2	--	14.8	--
192	Acc. drift	42.6	+ 1.4	41.8	- 3.2	15.6	+ 5.4
193	Exp. sub.	29.5	-29.8	50.1	+16.0	20.4	+37.8
201	Normal	32.0	--	52.4	--	15.6	--
202	Acc. drift	47.5	+48.4	40.5	-22.7	12.0	-23.1
203	Exp. sub.	27.5	-14.1	47.9	- 8.6	24.6	+57.7
221	Normal	43.0	--	45.0	--	12.0	--
222	Acc. drift	42.0	- 2.1	46.8	+ 4.0	11.2	- 6.7
223	Exp. sub.	35.0	-18.6	47.8	+ 6.2	17.2	+43.3

Table VI. (Continued)

		Sand		Silt		Clay	
Sample No.	Kind of Soil	Per Cent.	Diff. %	Per Cent.	Diff. %	Per Cent.	Diff. %
		Clay Loams					
71	Normal	29.8	--	50.2	--	20.0	--
72	Acc. drift	27.5	- 7.7	51.7	+ 3.0	20.8	+ 4.0
73	Exp. sub.	24.0	-19.5	53.6	+ 6.8	22.4	+12.0
261	Normal	39.0	--	49.8	--	11.2	--
262	Acc. drift	36.5	- 6.4	48.3	- 3.0	15.2	+35.7
263	Exp. sub.	39.5	+ 1.3	47.3	- 5.0	13.2	+17.9
31	Normal	22.0	--	57.2	--	20.8	--
32	Acc. drift	23.0	+ 4.5	56.6	- 1.0	20.4	- 1.9
33	Exp. sub.	34.0	+54.5	49.2	-14.0	16.8	-19.2
		Clays					
121	Normal	22.5	--	43.5	--	34.0	--
122	Acc. drift	23.0	+ 2.2	42.6	- 2.1	34.4	+ 1.2
123	Exp. sub.	18.0	-20.0	44.4	+ 2.1	37.6	+10.7
181	Normal	20.5	--	51.9	--	27.6	--
182	Acc. drift	3.5	-82.9	62.5	+20.4	34.0	+23.2
183	Exp. sub.	3.5	-82.9	60.5	+16.6	36.0	+30.5

materially, the individual samples varying from 16.7 per cent. to 46.3 per cent. with a mean loss of 33.3 per cent.

Table VII. Average mechanical analyses of some normal and eroded Alberta soils

	Sand		Silt		Clay	
Kind of Soil	Per Cent.	Diff. %	Per Cent.	Diff. %	Per Cent.	Diff. %
I. Fine Sands and Fine Sandy Loams, (7 Samples)						
Normal	72.3	--	19.9	--	7.8	--
Acc. drift	86.0	+18.9	8.8	-55.8	5.2	-33.3
Exp. sub.	75.8	+ 4.8	16.1	-19.1	8.1	+ 3.9
II. Loams and Silt Loams, (15 Samples)						
Normal	48.5	--	39.7	--	11.8	--
Acc. drift	56.8	+17.2	32.3	-18.6	10.9	- 7.6
Exp. sub.	47.0	- 3.1	38.7	- 2.5	14.3	+21.2
III. Clay Loams and Clays, (5 Samples)						
Normal	26.8	--	50.5	--	22.7	--
Acc. drift	22.7	-15.3	52.3	+ 3.6	25.0	+10.2
Exp. sub.	23.8	-11.2	51.0	+ 1.0	25.2	+11.0

In respect to the exposed subsurfaces of the fine sands and fine sandy loams, with which we should be vitally concerned, as in the drifted areas these are now the surface soils, we find a somewhat similar trend. The average increase in sand is less, being 4.8 per cent., and the decrease in silt averages 19.1 per cent. of the normal. However, in this case we have a slight increase in the clay fraction, namely by 3.9 per cent. of the normal sample.

It is apparent therefore that wind erosion has effected serious damage to the texture of these particular soils, both in regard to their accumulated drifts and their exposed subsurfaces.

In observing the data in Tables VI and VII for the loams and silt loams, we find considerable variation. In regard to the sand fraction in the accumulated drifts from these medium-textured soils, the range is from an increase of 48.4 per cent. to a loss of 14.6 per cent. The average for the fifteen samples gives a net increase of 17.2 per cent. in the sand content as compared to the normal surface soil. In regard to the two exceptions recorded, this decrease in the sand content in the drifts can be explained by the fact that although the wind appears to sift out the finer particles, depositing the coarser on the drifts, in these samples under discussion, the drifting had apparently advanced to the heavier subsurfaces, and this heavier material, drifting as granules, was also carried to the accumulated drifts.

The silt content of the accumulated drifts also varied considerably ranging from a loss of 81.5 per cent. to a gain of 11.5 per cent., but averaging a net loss of 18.6 per cent. However, there were only three samples in fifteen with higher silt reading and these were in the silt loam type rather than loams.

In observing the clay content of the accumulated drifts, the range is from a decrease of 33.3 per cent. to an

increase of 48.0 per cent. resulting in a net loss of 7.6 per cent. for the fifteen samples. The large increase of 48.0 per cent., and two of the other three samples with the higher clay readings, were from silt loams with heavier subsurfaces.

In the exposed subsurfaces of these medium-textured soils, there is a variation in sand from an increase of 16.0 per cent. to a decrease of 30.5 per cent., but averaging 3.1 per cent. below that of the normal surface. The silt content varies from a loss of 31.6 per cent. to a gain of 16.0 per cent., with a net loss of 2.5 per cent. In regard to the clay the range is from 11.5 per cent. below to 57.7 per cent. above normal, the average indicating an increase of 21.2 per cent. in clay.

On the whole then, the medium-textured soils have been affected considerably less by wind erosion than the fine sands and fine sandy loams. Although there has been a considerable increase in the sand and a loss in the silt content of the accumulated drifts, the data for the exposed subsurface samples, with which we should be more deeply concerned, indicate only minor changes in sand and silt, but a material increase in clay. This apparent resistance of the medium-textured soils to wind erosion has been noted by various authors (14,20,41,44,45).

In observing the data on the clays and clay loam soils, the tables show that the sand content of the accumulated

drifts varies from a slight increase (4.5 per cent.) to a decrease of 82.9 per cent., with average indicating a loss of 15.3 per cent. The exceptionally large decrease in sand in the one clay sample, namely No. 182, is not surprising when it is noted that this particular sample was the only one of this group which had drifted severely, leaving a heavier subsurface exposed to wind action.

The silt content in these accumulations exhibits smaller differences ranging from 3.0 per cent. below to 20.4 per cent. above normal, with an average increase of 3.6 per cent. The clay content varies from an insignificant loss in the case of one sample, to an increase of 35.7 per cent., with an average gain of 10.2 per cent.

The mechanical analyses of the exposed subsurfaces reveal a very similar trend to that of the accumulated drift samples. The sand fraction varies from 54.5 per cent. above normal to 82.9 per cent. below giving an average loss of 11.2 per cent. It should be pointed out that these two extremes are really exceptions in both cases as the one is a clay loam sample with a lighter subsurface, and the other, a clay, has a considerably heavier subsurface. The other individual samples in this group show only slight variation, so that the average figure is probably of more value than the degree of variation.

The silt content of the exposed subsurfaces exhibits narrow variations, that is from a loss of 14.0 per cent. to a

gain of 16.6 per cent. or the average is 1.0 per cent. above that of the normal. The clay fraction also varies both ways, that is from a decrease of 19.2 per cent. to an increase of 30.5 per cent. giving an average increase of 11.0 per cent.

It appears, therefore, that although there is considerable variability in some of the individual samples, on the average, the clay drift is only slightly higher in sand and lower in clay than the normal soil, the silt content remaining quite stable. The exposed subsurfaces of the fine-textured soils are also practically identical to the accumulated drifts in the case of these fine-textured soils.

Comparison of Results with Those from Other Sources.

In Table VIII is recorded the average mechanical analyses of some normal and eroded soils from Oklahoma, as listed by Daniel (12), and from Saskatchewan as determined by Moss (30). These results again are grouped into the three broad classes of coarse-textured, medium-textured and fine-textured soils. In comparing these data of Daniel and Moss with those in Table VII, it must be remembered that the writer's own results are computed according to the new standards of the United States Bureau of Soils (3) for silt and clay. Therefore, although the actual sand contents may be comparable in Tables VII and VIII, the silts and clays may not be cross compared. The new standards reduce the clay and raise the silt contents by approximately 25 per cent., but to overcome this approximation,

Table VIII. Average mechanical analyses of some normal and eroded soils from Oklahoma and Saskatchewan

	Sand		Silt		Clay	
Kind of Soil	Per Cent.	Diff. %	Per Cent.	Diff. %	Per Cent.	Diff. %
A - Daniel (Oklahoma)						
I. Coarse-textured Soils (24 Samples)						
Normal#	70.4	--	14.3	--	15.3	--
Acc. drift	86.1	+22.3	5.6	-60.9	8.3	-45.8
Subsurface	65.2	- 7.4	12.2	-14.7	22.6	+47.7
II. Medium-textured Soils (26 Samples)						
Normal	50.5	--	23.9	--	25.6	--
Acc. drift	69.6	+37.8	13.0	-45.7	17.4	-32.1
Subsurface	50.4	- 0.2	18.5	-22.6	31.1	+21.4
III. Fine-textured Soils (11 Samples)						
Normal	39.2	--	26.2	--	34.6	--
Acc. drift	51.4	+31.1	19.0	-27.5	29.6	-14.5
Subsurface	38.0	- 3.1	22.8	-13.0	39.2	+13.2
B - Moss (Saskatchewan)						
I. Sandy Loams (5 Samples)						
Normal##	70.0	--	11.7	--	13.6	--
Acc. drift	84.6	+20.9	5.8	-50.4	9.4	-30.9
II. Loams and Clay Loams (9 Samples)						
Normal	34.1	--	35.7	--	24.2	--
Acc. drift	50.4	+47.8	26.1	-26.9	20.5	-15.3
III. Clay Soils (9 Samples)						
Normal	10.2	--	19.9	--	60.5	--
Acc. drift	10.7	+ 4.9	19.9	0	60.5	0

#The normal soil used by Daniel was virgin surface soil.
" " " " " Moss " cultivated " " .

it was deemed best to draw comparisons only between the percentages of loss or gain rather than between the actual amounts present.

In comparing the differences in the sand content of the accumulated drifts in the coarse-textured soils in Tables VII and VIII surprisingly close results are noted in all three cases. The increases range between 18.9 per cent. and 22.3 per cent., the writer's own figure being the lowest of the three. In regard to the silt fraction, the losses are all very high, varying from 50.4 per cent. to 60.9 per cent., the writer's own figure in this case being intermediate to the two listed. Again, the clay content in all cases, indicates a considerable loss, namely from 30.9 per cent. to 45.8 per cent. with the writer's figure falling between these two.

In respect to the subsurface samples, no data were available in the study conducted in Saskatchewan. The data for the subsurface samples of the Oklahoma soils, as listed in Table VIII are not altogether comparable to the writer's own work, as in the former case the samples were actually taken at a depth of 12 to 18 inches, whereas in the latter case, as previously noted, the exposed subsurfaces was used. However, these two locations are very close to the same horizon of the soil profile.

From Tables VII and VIII we note then, that in the coarse-textured soils, the difference in the sand content of

the exposed subsurfaces is slightly above in the former case, and slightly below the normal in the latter case. However, in both tables there are substantial decreases in the silt fraction. In regard to the clay in the exposed subsurfaces, we note increases in both tables, though an insignificant one in Table VII.

On the whole then, surprisingly close corroboration is noted in three sets of results, indicating that to the coarse-textured soils wind erosion has effected grave damage. That is, in the accumulations, the sand content of these already too sandy soils is increased considerably and the silt and clay have very materially been removed. In these subsurface samples, the sand content approximates that of the normal, but there is a significant decrease in silt and an increase in clay.

In regard to the medium-textured soils it is observed from Tables VII and VIII, that both Daniel and Moss obtained their greatest increases in the sand content in the accumulated drift samples. The writer's results are somewhat lower than the other two. However, in all three cases, the actual sand content in the drifts of these medium-textured soils is not equal to that of the coarse-textured soils. In regard to the silt content in the accumulated drifts of these soils, we have consistent and significant decreases. In all cases, however, the losses of silt are less than in the coarse-textured soils. A consistent loss is also noted in the clay fraction in the

three sets of data, which is also consistently less than in the lighter soils.

In comparing the subsurface samples of the medium-textured soils, it is observed that both in the Oklahoma and Alberta soils, the subsurfaces have remained practically of the same sand content as the normal surfaces. In Oklahoma, however, the figures indicate a considerable loss of silt, whereas the writer's results exhibit a very small loss. The clay content of these subsurfaces is substantially higher in both cases.

It appears, therefore, that although wind sortation has effected considerable changes in the accumulated drifts of the medium-textured soils, still the actual percentages of sand are significantly lower, and the losses of silt and clay considerably less than is the case in the coarse-textured soils. It also is observed that the mechanical analyses of the sub-surface samples in both tables approximate that of the normal soils.

The physical analyses of fine-textured soils as affected by wind erosion exhibit quite different trends. In the accumulated drifts of the samples from Oklahoma the sand content is somewhat increased. However, Moss obtained a very slight increase and the writer's own results exhibit a decrease in the sand fraction. The figures for silt indicate a better agreement. Although Daniel obtained a significant decrease of

this constituent, Moss's figure is identical to the normal soil, and the writer's is practically the same as that of Moss. In the clay content, Daniel's figures indicate a slight decrease, Moss's are identical again, and the writer's exhibit a slight increase of this constituent in the drift samples.

In the subsurface samples of the fine-textured soils, both the Oklahoma and Alberta results indicate a slight decrease in sand and an increase in clay, with a minor variation in the silt content. In other words, the subsurface samples are only slightly heavier than the normal surface in these samples.

In regard to the effects of wind erosion on fine-textured soils, insofar as mechanical analyses are concerned, there appears then to be conflicting results. In the case of the accumulated drifts, Daniel found that in Oklahoma, a significant increase in sand occurred, with decreases in silt and clay. Moss's figures indicate that the drift is identical to the normal. The writer's own results approximate those of Moss. In regard to the subsurface samples, the two tables reveal that in the fine-textured soils, the subsurfaces are only slightly heavier than the normal surfaces.

Conclusions. In concluding this section on the effects of wind erosion on the mechanical analyses of soils, several observations are recorded:

(1) In the accumulations from coarse-textured soils, there was a large increase in sand, in conjunction with the

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In the [illegible] of the [illegible] soils, both the [illegible] decrease in [illegible] increase in clay, with a [illegible] in the silt content. In other words, the [illegible].

In regard to the effect of [illegible] on [illegible] soils, [illegible] analyses are concerned, [illegible] results. [illegible] significant increase [illegible], with [illegible] silt and clay. [illegible]. The [illegible]. In regard to the [illegible] soils, [illegible] only slightly [illegible].

Conclusions. [illegible] the effects [illegible] of the [illegible]:

(1) In the [illegible] soils, [illegible] had a [illegible] in [illegible], in [illegible] the

loss of one half the silt and one third the clay. The subsurfaces also indicate significant decreases of the silt fraction. These results were closely corroborated by other investigators in Oklahoma and Saskatchewan.

(2) In the accumulations from medium-textured soils, the increase in sand was slightly less, and the losses in silt and clay were significantly less than in the lighter soils. The exposed subsurfaces indicated significant increases in clay with slight losses of silt and sand. These results in the medium-textured soils were not altogether in accordance with those of Saskatchewan and Oklahoma.

(3) In regard to the fine-textured soils, the accumulated drifts and the exposed subsurfaces varied only slightly from the normal surface samples. These results were in agreement with those from Saskatchewan, but in the Oklahoma samples a certain degree of wind sortation had also occurred on these heavier soils.

IV. Chemical Analyses

Certain chemical analyses were conducted on the normal and drifted soils to determine the effects of wind erosion on the chemical composition of the soil as an indication of its fertility. The total nitrogen and the organic matter content were determined by the methods as previously noted, on all of the normal, accumulated drift, and exposed subsurface

samples. In addition total and acid soluble phosphorus were ascertained, but on too limited a number of samples to warrant drawing any observations therefrom. These latter results therefore were not recorded.

However, Dr. Shutt (39) has pointed out that nitrogen and organic matter are the primary indices of soil fertility. This point also was borne out quite significantly by the pot experiment as outlined in an earlier section of this paper. It would appear reasonable then, to make observations as to the soil fertility, on the results of the analyses of these two soil constituents.

Results and Discussion. In Table IX is recorded a complete list of the nitrogen and organic matter contents and the carbon: nitrogen ratios of all the normal, accumulated drift and exposed subsurface samples collected. The percentage variation also is included in each case. The samples are grouped according to soil type for convenience in making comparisons. The average composition of these soil samples also is computed according to the three broad classes as previously noted. These latter results are reported in Table X.

In examining these two tables then, it is observed that in the accumulated drifts of the fine sands and fine sandy loams, the loss in nitrogen varies from 27.9 per cent. to 70.5 per cent. giving a mean loss of 54.9 per cent. The decrease in organic matter is slightly higher, ranging from 32.5 per cent. to 77.2 per cent. with the average of 57.9 per cent.

Table IX. Chemical analyses of some normal and eroded Alberta soils

Sample No.	Location	Nitrogen %	Diff.[#] %	Organic Matter %	Diff.[#] %	C:N Ratio
		Fine Sands				
11	Normal[##]	.099	--	1.84	--	10.8
12	Acc. drift[x]	.041	-58.5	0.74	-59.8	10.5
13	Exp. sub.[xx]	.030	-69.7	0.60	-67.4	11.7
21	Normal	.160	--	3.36	--	12.2
22	Acc. drift	.080	-50.0	1.33	-60.4	9.6
23	Exp. sub.	.096	-40.0	1.31	-61.0	7.9
231	Normal	.098	--	2.09	--	12.3
232	Acc. drift	.051	-48.0	1.41	-32.5	16.1
233	Exp. sub.	.079	-19.4	1.09	-47.8	8.0
271	Normal	.190	--	3.86	--	11.8
272	Acc. drift	.056	-70.5	0.88	-77.2	9.1
273	Exp. sub.	.117	-38.4	1.81	-53.1	9.0
		Fine Sandy Loams				
61	Normal	.140	--	2.93	--	12.1
62	Acc. drift	.101	-27.9	1.98	-32.5	10.4
63	Exp. sub.	.128	- 8.6	2.05	-30.1	9.3
101	Normal	.211	--	4.55	--	12.5
102	Acc. drift	.092	-56.4	1.72	-62.2	10.9
103	Exp. sub.	.127	-39.8	2.55	-44.0	11.6
241	Normal	.170	--	2.81	--	9.6
242	Acc. drift	.059	-65.3	1.12	-51.6	11.0
243	Exp. sub.	.126	-25.9	1.93	-35.2	8.9

[#] All differences are calculated in the normal as the standard.

[##] Normal refers to normal cultivated surface soil in each case except sample 271 where virgin sod was used.

[x] Acc. drift refers to the accumulated drift samples.

[xx] Exp. sub. refers to the exposed subsurface samples.

Table IX. (Continued)

Sample No.	Location	Nitrogen %	Diff. %	Organic Matter %	Diff. %	C:N Ratio
Loams						
81	Normal	.185	--	3.60	--	11.3
82	Acc. drift	.223	+20.5	4.65	+29.0	12.1
83	Exp. sub.	.176	- 4.9	3.83	+ 6.4	12.6
91	Normal	.167	--	2.88	--	10.0
92	Acc. drift	.087	-47.9	1.97	-31.6	13.1
93	Exp. sub.	.167	0	2.86	- 0.6	9.9
141	Normal	.698	--	14.81	--	12.3
142	Acc. drift	.269	-61.4	6.64	-55.2	14.3
143	Exp. sub.	.312	-55.3	6.33	-57.2	11.8
151	Normal	.294	--	6.67	--	13.2
152	Acc. drift	.188	-36.1	4.26	-36.1	13.1
153	Exp. sub.	.252	-14.3	5.37	-19.5	12.3
161	Normal	.210	--	4.50	--	12.4
162	Acc. drift	.121	-42.4	2.62	-41.8	12.6
163	Exp. sub.	.197	- 6.2	4.26	- 5.5	12.5
211	Normal	.192	--	4.05	--	12.2
212	Acc. drift	.167	-13.0	3.50	-13.6	12.2
213	Exp. sub.	.206	+ 7.2	4.36	+ 7.8	12.3
251	Normal	.253	--	4.17	--	9.6
252	Acc. drift	.229	- 9.5	4.15	- 0.5	10.5
253	Exp. sub.	.204	-19.4	3.42	-18.0	9.7

Table IX. (Continued)

Sample No.	Location	Nitrogen %	Diff. %	Organic Matter %	Diff. %	C:N Ratio
Silt Loams						
41	Normal	.208	--	3.69	--	10.3
42	Acc. drift	.210	+ 1.0	3.71	+ 0.5	10.2
43	Exp. sub.	.199	- 4.3	3.10	-17.0	9.0
51	Normal	.175	--	3.42	--	11.3
52	Acc. drift	.174	- 0.6	3.17	- 7.3	10.6
53	Exp. sub.	.175	0	3.24	- 5.3	10.7
111	Normal	.226	--	4.10	--	10.5
112	Acc. drift	.205	- 9.3	3.12	-23.9	8.8
113	Exp. sub.	.114	-49.6	2.50	-39.0	12.3
131	Normal	.154	--	2.97	--	11.2
132	Acc. drift	.163	+ 5.8	3.14	+ 5.7	11.2
133	Exp. sub.	.146	- 5.2	2.81	- 5.4	11.2
171	Normal	.333	--	6.50	--	11.3
172	Acc. drift	.303	- 9.0	6.16	- 5.2	11.8
173	Exp. sub.	.269	-22.3	5.43	-16.4	11.7
191	Normal	.400	--	8.28	--	12.0
192	Acc. drift	.544	+36.0	11.96	+44.5	12.8
193	Exp. sub.	.433	+ 8.3	9.54	+15.2	12.8
201	Normal	.267	--	5.38	--	11.7
202	Acc. drift	.343	+28.5	7.26	+34.8	12.3
203	Exp. sub.	.234	-12.4	4.47	-16.9	11.1
221	Normal	.301	--	6.31	--	12.2
222	Acc. drift	.262	-12.9	5.40	-14.4	11.9
223	Exp. sub.	.273	- 9.3	5.55	-12.0	11.8

Table IX. (Continued)

Sample No.	Location	Nitrogen %	Diff. %	Organic Matter %	Diff. %	C:N Ratio
			Clay Loams			
31	Normal	.271	--	5.04	--	10.7
32	Acc. drift	.265	- 2.2	5.04	0	11.0
33	Exp. sub.	.226	-16.6	4.50	-10.8	11.5
71	Normal	.217	--	4.11	--	11.0
72	Acc. drift	.250	+15.2	4.60	+11.8	10.7
73	Exp. sub.	.186	-14.3	3.24	-21.2	10.1
261	Normal	.260	--	4.97	--	11.1
262	Acc. drift	.302	+16.2	4.92	- 1.1	9.4
263	Exp. sub.	.218	-16.2	3.86	-22.4	10.3
			Clays			
121	Normal	.447	--	8.98	--	11.7
122	Acc. drift	.483	+ 8.1	9.40	+ 4.8	11.3
123	Exp. sub.	.365	-18.3	7.17	-20.1	11.4
181	Normal	.305	--	6.33	--	12.0
182	Acc. drift	.157	-48.6	2.97	-53.1	11.0
183	Exp. sub.	.124	-59.3	2.21	-65.1	10.3

Table X. Average chemical analyses of some normal and eroded Alberta soils

Kind of Soil	Nitrogen %	Diff. %	Organic Matter %	Diff. %	C:N Ratio
I. Fine Sands and Fine Sandy Loams (7 Samples)					
Normal	.153	--	3.06	--	11.6
Acc. drift	.069	-54.9	1.31	-57.9	11.1
Exp. sub.	.100	-34.6	1.67	-45.4	9.5
II. Loams and Silt Loams (15 Samples)					
Normal	.271	--	5.42	--	11.4
Acc. drift	.233	-14.1	4.78	-11.8	11.8
Exp. sub.	.224	-17.3	4.47	-17.5	11.4
III. Clay Loams and Clays (5 Samples)					
Normal	.300	--	5.89	--	11.3
Acc. drift	.291	- 3.0	5.33	- 9.5	10.7
Exp. sub.	.224	-25.3	4.20	-28.7	10.7

In the exposed subsurfaces of these soils, the differences in nitrogen and organic matter, as compared to the normal soil, follow a similar trend to that of the accumulated drifts. The decreases, however, are not as great. In regard to nitrogen, the figures range from 8.6 per cent. to 69.7 per cent., or an average decrease of 34.6 per cent. Again in organic matter, the reduction is higher than for nitrogen, ranging from 30.1 per cent. to 67.4 per cent., the average for the seven samples being 45.4 per cent.

It is evident consequently, that the wind has very seriously impaired the fertility of these coarse-textured soils, removing one half the total nitrogen and organic matter from

the drift, accompanied by decreases of over one third of these two constituents in the exposed subsurface. This last point appears contradictory to the results of the pot experiment, in which case it was noted that the exposed subsurface samples yielded the least. However, by examining the individual samples used in that experiment, namely samples 11, 12 and 13, it is observed that these varied from the average, as in this case the exposed subsurface contained less nitrogen and organic matter than the accumulated drift.

It also should be pointed out in regard to the carbon:nitrogen ratio (in the tables and subsequently, termed C:N ratio), considerable variation is noted. In the averages for the coarse-textured soils it is 11.6:1 (the "1" being omitted in the tables and hereafter in the discussion), 11.1 and 9.5 respectively for the normal, drift and exposed subsurface samples. The lower C:N ratio in the subsurface agrees with observations of Salter (36), indicating that with the ageing of organic matter, as normally occurring in the subsoil, the ratio is narrowed. The C:N ratio in the drift samples, intermediate to the other two then indicates apparently, a mixture of fresh organic matter from the top soil and that more decayed from the subsurface. This theory is quite plausible, as in these coarse-textured soils, severe drifting had occurred. The C:N ratio, being narrower in the accumulated drift than in the normal soil, as noted in the last column of

Table X, also indicates a greater loss of carbon (or of organic matter), than of nitrogen. This point was noted previously in these coarse-textured soils.

In regard to the medium-textured soils, that is the loams and silt loams, we note considerable variation in the results. Comparing the accumulated drift samples, the differences in the nitrogen contents range from an increase of 36.0 per cent. to a loss of 61.4 per cent. with the net result being -14.1 per cent. It is interesting to note that from five increases in the fifteen samples, four occur in the "silt loam" rather than the lighter "loam" type. The figures for the variation of the organic matter are quite similar, ranging from a gain of 44.5 per cent. to a loss of 55.2 per cent. giving a mean loss of 11.8 per cent.

Examining the data for the subsurfaces of these medium-textured soils we note that the nitrogen content varies from a loss of 55.3 per cent. to slight increases in two exceptional cases. However, these increases in samples 193 (silt loam) and 213 (loam) are within the range of sampling error. The average difference indicates a loss of 17.3 per cent. The results for the variability of organic matter follow a similar trend, ranging from a loss of 57.2 per cent. to minor gains in three cases, giving a net average loss of 17.5 per cent.

Considering these results it appears that wind erosion has caused only minor damage to the medium-textured

soils, both in regard to their accumulations and their exposed subsurfaces. From this fact, it may be deduced that drifting has been less severe, or that these soils have exceptionally deep "A" horizons in their soil profiles. The former theory is more tenable, as the resistance of medium-textured soils to wind erosion has been observed by different investigators (14,20,23,30,41,44,45). This point also is substantiated in the previous section on the description of the samples, that is, in the last column of Table I. It is here recorded that drifting had been severe only in one of the fifteen samples of loams and silt loams, with twelve moderately drifted, and two indicating only slight erosion.

The mean C:N ratio, as recorded in the last column of Table X again appears to corroborate this previous statement. It is noted here that the C:N ratios of the normal surface and the exposed "subsurface" are equal. This indicates that the composition of the organic matter is substantially the same in both cases, indicating apparently that the normal surface soil has not been removed by the wind to any great extent.

In regard to C:N ratio for the accumulated drift, in this case it is higher than that of the normal surface, namely 11.8 compared to 11.4. This fact would lead one to believe that the coarse and undecomposed organic matter have been accumulated in the drifts. This point has also been substantiated by Daniel and Langham (13).

In observing the data for the fine-textured soils, that is the clays and clay loams, we note variable results. The averages, however, seem of considerable interest. In the accumulated drifts of these soils, the differences in nitrogen range from a gain of 16.2 per cent. to the very significant loss of 48.6 per cent. in one case, giving a net loss of 3.0 per cent. It might be noted here that this exceptional loss occurred on a clay sample (No. 182) which had drifted severely. The results for organic matter quite closely follow those of nitrogen in these accumulated drift samples, ranging from an increase of 11.8 per cent. to a loss of 53.1 per cent., with mean of -9.5 per cent.

In regard to the exposed subsurfaces, the results are more consistent. That is we note losses in nitrogen in each individual case, ranging from 14.3 per cent. to 59.3 per cent. with a mean loss of 25.3 per cent. Similarly for organic matter, the losses range from 10.8 per cent. to 65.1 per cent. with the average loss of 28.7 per cent.

In view of these results, particularly the averages in Table X, it may be observed that on the whole, the drift from the heavier soils approximates the composition of the surface soil from which it was derived. This would lead one to assume then that the clayey soils drift in the form of granules allowing little wind sortation to occur.

Also it was noted that the subsurface samples were quite significantly damaged by wind erosion, more so than in

the case of the medium-textured soils. It appears then, that the clayey soils are affected by drifting, intermediately to the sands and the loams. The C:N ratio appears further to substantiate the conclusion. The average C:N ratio is significantly lower (10.7) in the exposed subsurface than in the normal surface (11.3). It was noted that in the loams, the ratios were identical, namely 11.4 in both cases, whereas those in the coarse-textured soils varied to the greatest extent, being 11.6 and 9.5, indicating severe erosion.

Comparison of Results with Data from Other Sources.

In Table XI is presented the average chemical analyses of some normal and eroded soils as recorded by Daniel and Langham (13) in Oklahoma, by Ellis (16) in Manitoba and Moss (30) in Saskatchewan. These investigators compared only the normal surfaces and the accumulated drifts, determining the nitrogen and the organic matter. Moss had also determined the total phosphorus, which indicated significant losses in the drift samples, but these data are not here recorded. Ellis only recorded the loss in organic matter, soil types not being listed. It should also be noted that since Moss had determined the organic matter as the loss on ignition, the C:N ratio, if determined would not have been on a comparable basis to that of the writer. This ratio is included for the Oklahoma samples where the organic matter was determined by the chromic acid reduction method as was also used by the writer (1).

Table XI. Average chemical analyses of some normal and eroded soils from Oklahoma, Manitoba and Saskatchewan

Kind of Soil	Nitrogen %	Diff. %	Organic Matter %	Diff. %	C:N Ratio
A - Daniel and Langham (Oklahoma)					
I. Coarse-textured Soils (24 Samples)					
Normal#	.066	--	1.51	--	13.5
Acc. drift	.040	-39.4	1.06	-29.8	15.4
II. Medium-textured Soils (26 Samples)					
Normal	.093	--	2.11	--	13.2
Acc. drift	.087	- 6.4	2.11	0	14.1
III. Fine-textured Soils (11 Samples)					
Normal	.110	--	2.33	--	12.2
Acc. drift	.107	- 2.7	2.48	+ 6.4	13.4
B - Ellis (Manitoba)					
(2 Samples					
Normal	--	--	11.5##	--	--
Acc. drift	--	--	5.5	-52.2	--
C - Moss (Saskatchewan)					
I. Sandy Loam Soils (5 Samples)					
Normal	.171	--	3.78##	--	--
Acc. drift	.092	-46.2	2.08	-44.9	--
II. Loam and Clay Loam Soils (9 Samples)					
Normal	.238	--	6.22	--	--
Acc. drift	.233	- 2.2	5.63	- 9.5	--
III. Clay Soils (9 Samples)					
Normal	.324	--	8.13	--	--
Acc. drift	.308	- 4.9	7.82	- 3.9	--

#Normal soils refer to normal cultivated soils in all cases.
##Organic matter taken as loss on ignition.

In examining Tables X and XI for the variation in the nitrogen content of the coarse-textured soils, it is observed that in each case for both the total nitrogen and organic matter, greatest losses occurred in this soil class. The losses in nitrogen range from 39.4 per cent. to 54.9 per cent., with the writer's results agreeing closely with those of Moss, namely 54.9 per cent. and 46.2 per cent. respectively. Similarly, large losses occurred in the organic matter in all cases.

There is, however, a point of conflict in these results for the coarse-textured soils in regard to the C:N ratios. The ratios themselves cannot be compared in different climates as pointed out by Salter (36), but the trends should be similar. However, in the drift samples, the Oklahoma results indicate a wider ratio than for the normal surface, while for the Alberta samples it is somewhat narrower in this case, being wider, however, in the medium-textured soils. Daniel and Langham (13) explain this widening of the C:N ratio by the fact that in the drifts frequently large amounts of undecomposed vegetation were found to accumulate.

It may therefore be concluded that wind erosion has caused very serious damage to the fertility of the coarse-textured soils, figures from three different sources indicating losses of 1/3 to 1/2 of the total nitrogen and the organic matter content of the normal cultivated soils.

In regard to the medium-textured soils, it is noted from Tables X and XI that both the Oklahoma and the Saskatchewan samples indicate only minor losses in nitrogen and organic matter, varying up to 9.5 per cent. In the Alberta samples the losses are slightly higher, being 14.1 per cent. for nitrogen and 11.8 per cent. for the organic matter content of these soils. In this class, the C:N ratios are slightly higher in the drifts in both tables, indicating the presence of coarse, undecomposed organic matter, with part of the finer humus removed by the wind.

It would thus seem reasonable to conclude that wind erosion has caused only minor losses to the fertility of the accumulations from medium-textured soils.

Comparing the two tables again for the average nitrogen and organic matter contents of the fine-textured soils, it is observed that in the accumulated drifts, only slight, and probably insignificant differences have occurred in all three cases, the variation being from a gain of 6.0 per cent. to a loss of 9.5 per cent. It would therefore seem safe to say that the accumulated drift of fine-textured soils is practically identical to the normal, cultivated surface soil.

Summary. (1) In coarse-textured soils, the writer's data indicate that very serious damage has been caused by wind erosion, the accumulated drifts having lost over 1/2 the total nitrogen and organic matter, these constituents

also being reduced by over 1/3 in the exposed subsurfaces.

(2) In regard to medium-textured soils, wind damage has been considerably less, average losses of 12 per cent. to 18 per cent. of the total nitrogen and organic matter occurring in both the drifts and the exposed subsurfaces.

(3) In respect to the fine-textured soils, the wind damage is variable. The accumulations from these heavy soils are practically identical to the normal surface soils. However, the exposed subsurfaces indicate considerable damage with losses of 1/4 of their nitrogen and their organic matter.

(4) Data from Oklahoma and Saskatchewan corroborate the writer's conclusion that the coarse-textured soils have suffered most severely from wind erosion.

(5) In regard to the medium-and ~~coarse~~ fine-textured soils, the other investigators, having studied only the accumulated drifts in relation to the normal soil, found only slight reductions in fertility.

V. Dust Analyses

A study of the dust, which is carried aloft by the winds to varying heights, and away to considerable distances during periods of wind erosion, has not received sufficient emphasis. In the past mention has been made of these dust clouds on various occasions. With the continued drought of

the past several years these "black blizzards" have assumed nation-wide importance. As an indication of the extent of these dust clouds, it was reported (2) in the spring of 1933, that soil material of a reddish character, apparently from the "dust bowl" states, was deposited by the wind on the dark soils of Iowa in sufficient quantity to give them a reddish tinge. However, in 1934, Lowdermilk (27) notes that for the first time in history, dust clouds from Kansas, Colorado, Oklahoma, and Texas rolled across the continent and into the Atlantic Ocean. This "dust fog" is reported to have extended 1,000 miles north and south by 1,500 miles east and west.

The character of these dust blankets was studied at Washington, D.C. by Hand (22), and at Baton Rouge, Lousiana by Russell and Russell (35). The latter state that aviators were forced to ascend to 6,000 feet to overcome poor visibility. The Russells collected some of this dust and subjected it petrographic examination. The sizes of particles ranged up to 0.15 mm. (fine sand), but over 50 per cent. were reported as below 0.005 mm. (former limit for clay). The examination revealed that the samples contained quartz, feldspar, calcite, hematite, limonite, muscovite (mica), volcanic ash, and considerable organic matter. However, no actual chemical analyses were apparently carried out on the sample.

At Washington, D.C., Hand noted that a dust fog occurred a month later. The height of the cloud, according to the [illegible] these "Kansas [illegible]" [illegible] nation-wide importance. In an investigation of the [illegible] of these dust clouds, it was recorded (4) [illegible] in 1933, [illegible] material of a reddish [illegible], [illegible] from the "dust bowl" section, was transported by the wind to the [illegible] of Iowa in sufficient quantity to give snow a reddish tinge. However, in 1934, [illegible] (47) notes that for the first time in history, dust clouds from Kansas, Nebraska, Oklahoma, and Texas [illegible] across the continent and into the Atlantic ocean. This "dust fog" is reported to have extended 1,000 miles [illegible] and [illegible].

The occurrence of these dark rainfalls was [illegible] at Washington, D.C., on [illegible], and at other points, [illegible] by Russell and [illegible]. [illegible]

[illegible]

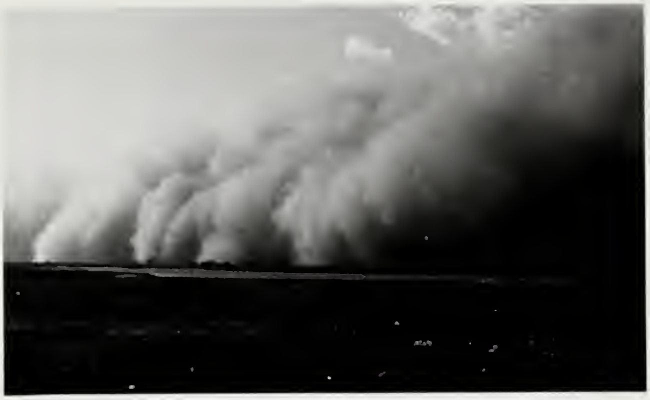
At Washington, D.C., [illegible]

aerological observations, was 6,500 feet, and the dust was heavy enough to reduce solar radiation by 75 per cent. The weight above one square mile was calculated to be 101 tons. In size, the particles ranged from 0.13 mm. (fine sand) to 0.001 mm. (colloid), no percentages being reported. According to examination, the dust contained the minerals as noted above, and "considerable organic matter".

Similar dust storms or "black blizzards" have occurred in Alberta, especially in the past few years (see Plate III). These occur especially in the spring, but over a term of years, may be observed in any season. A recent report (15) indicates that a large dust cloud was observed in mid-winter extending up 9,000 feet above the city of Lethbridge.

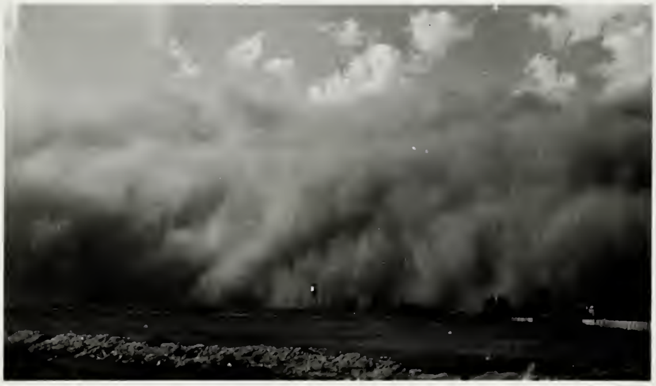
However, no actual analyses of these dust depositions were conducted, as far as could be ascertained until 1935, when Fly (18) issued a report on the chemical and mechanical analyses of dust deposited by wind in Oklahoma. No references could be found covering such tests conducted in Canada.

Material and Methods. In Tables XII and XIII are listed respectively, the chemical and mechanical analyses of dust samples from Alberta, as determined by the writer, and Oklahoma as reported by Fly (18), compared to their normal surface soils.



(Courtesy of W. Prowse)

Fig. 1. Side view of approaching dust storm. Taber, Alberta, June 2, 1937.



(Courtesy of W. Prowse)

Fig. 2. Approach of same dust storm as in Fig. 1, as appearing from the front.

Plate III. Views of Approaching Dust Storm, Taber, Alberta, 1937.

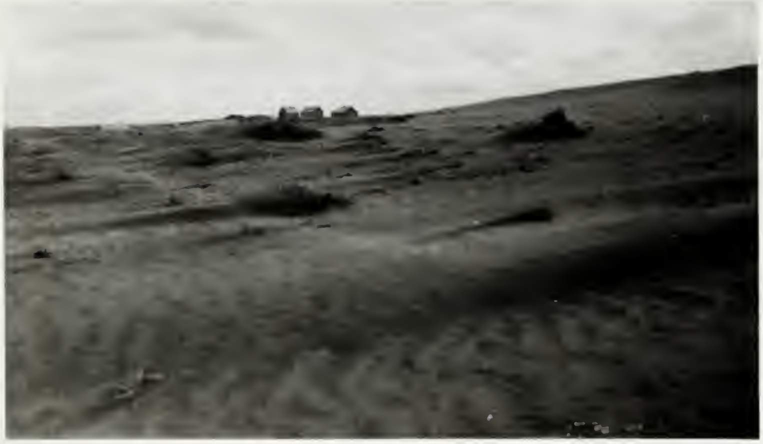


Fig. 1. Damage to soil by accumulations of drift around stationary objects in field. South of Monitor, Alberta.

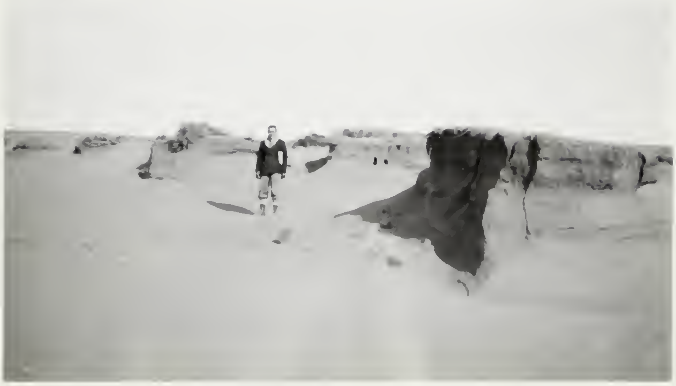


Fig. 2. Damage to cultivated field by excessive wind removal of soil in area adjacent to that in Fig. 1.

Plate IV. Illustrations of Soil Damage by Accumulations and Removal.

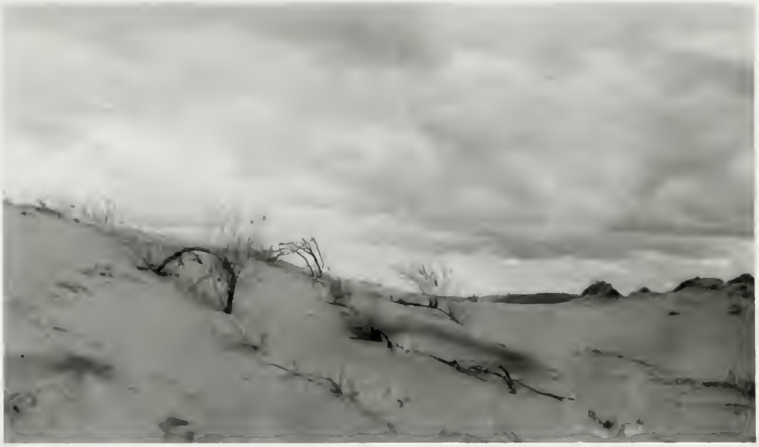
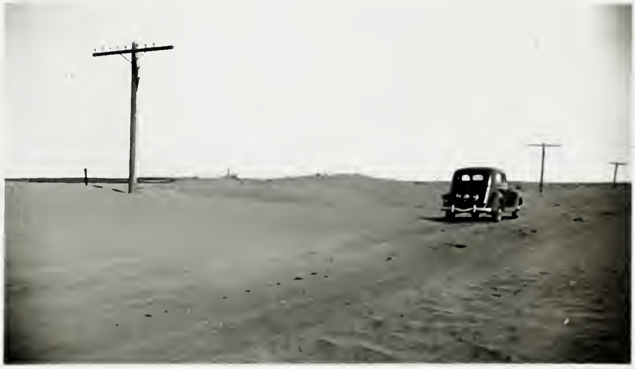


Fig. 1. Damage of wind erosion to bush growth. Observed near Empress, Alberta.



(Courtesy of Economics Department, University of Alberta)

Fig. 2. Partial obliteration of fence by wind depositions. Near Youngstown, Alberta.

Plate V. Wind Damage to Bush Growth and Fence Line.

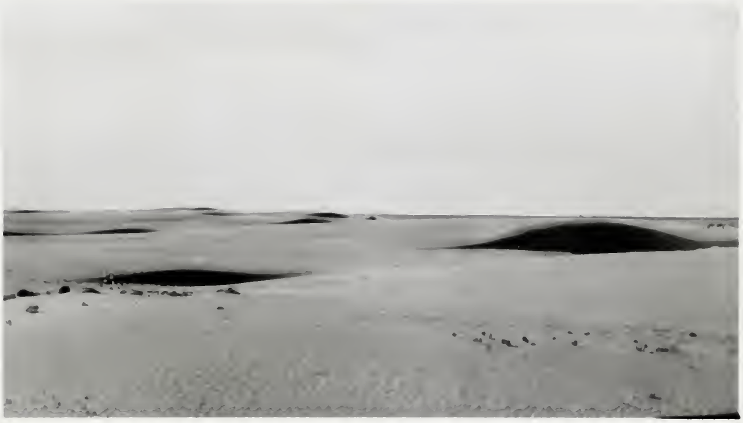


Fig. 1. Illustration of severe wind erosion, as observed north of Medicine Hat, along Saskatchewan-Alberta border.

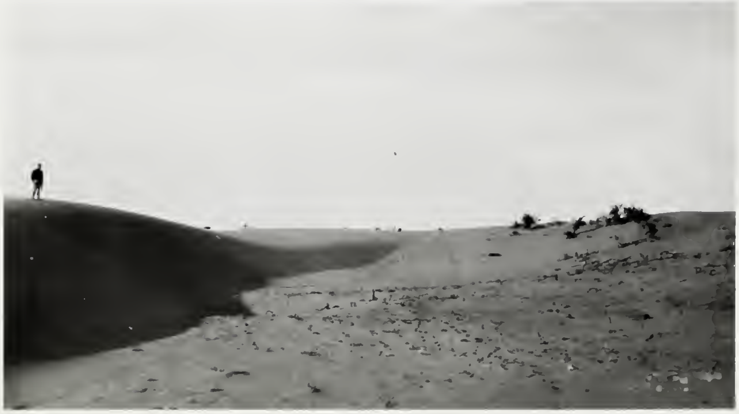


Fig. 2. Another view taken close to Fig. 1, depicting the immense accumulations of drift.

Plate VI. Severe Wind Erosion Along the Saskatchewan-Alberta Border.

It might be noted here that samples 134 to 137, as recorded in the tables, were collected at various heights in an inhabited residence. This was located in a silt loam area, with a large area of fine sandy loam commencing two miles southwest. Bordering this was a still larger area of loam soil.

Samples 274 and 275 were collected at two different heights from an abandoned house situated in a fine sand area, with a fine sandy loam area again two miles southwest of it and extending several miles in width. West of this again was a large loam area.

The mechanical and chemical analyses were conducted on these samples similarly to the soil samples. The only variation used was that for the chemical analyses, no pulverizing was required. An 80 mesh screen was used on all samples to remove any extraneous material.

Chemical Analyses. From Table XII on the analyses of dust from points in Alberta and Oklahoma, it appears quite evident that the dust carried by the wind, even at relatively small heights, is very rich in plant nutrients. The analyses of the silt loam samples, namely 131 to 137, indicate that although the accumulated drift and the exposed subsurface were nearly the same as the normal surface soil, yet the dust deposits, collected at 5 feet, 15 feet and 25 feet above the ground level, are from 61 per cent. to 115 per cent. higher in

Table XII. Chemical analyses of dust from two points in Alberta and one in Oklahoma (by Fly), compared to soils "in situ"

Sample No.	Location	Nitrogen %	Diff. %	Organic Matter %	Diff. %
	Silt Loam Soil (Barons)				
131	Normal	.154	--	2.97	--
132	Acc. drift	.163	+ 5.8	3.14	+ 5.7
133	Exp. sub.	.146	- 5.2	2.81	- 5.4
	Dust				
134	Dust - 5'	.268	+74.0	5.07	+70.8
135	" 15'	.248	+61.0	4.43	+49.0
136	" 25'	.297	+92.8	5.29	+78.0
137#	" 25'	.331	+115.0	5.31	+78.5
Average of dust (4)		.286	+85.8	5.03	+69.2
	Fine Sandy Soil (Carmangay)				
271##	Normal	.190	--	3.86	--
272	Acc. drift	.056	-70.5	0.88	-77.2
273	Exp. sub.	.117	-38.4	1.81	-53.1
	Dust				
274	Dust - 5'	.389	+105.0	7.17	+85.8
275	" 15'	.388	+104.2	6.41	+66.0
Average of dust (2)		.389	+105.0	6.79	+75.9
Av. of all dust (6)		.320	+95.4	5.61	+72.6

Sample No.	Location	Nitrogen %	Diff. %	O.M. (Loss on Ignition)	Diff. %
	Silt Loam Soil - Fly (Goodwell, Oklahoma)				
13	Normal	.074	--	3.06	--
1	Acc. drift	.085	+14.8	3.68	+20.2
	Dust from Bldgs., etc.				
Av. of 15 samples		.159	+115.0	5.41	+76.8

#Collected a year previously to the samples above.

##Normal sample was taken from sod, as normal cultivated fine sand was not available in proximity.

nitrogen than the normal cultivated surface. The average of the four dust samples indicates an increase of 85.8 per cent. in nitrogen. The figures for organic matter are slightly lower, indicating that the wind has carried away the richer, more decomposed organic matter. They range from 49.0 per cent. to 78.5 per cent. with the average increase of 69.2 per cent. in organic matter.

In the section of Table XII on the fine sand samples, a similar trend is noted. Here, however, the accumulated drift also exhibits a large decrease in nitrogen and organic matter. The dust deposits at 5 feet and 15 feet were almost identical indicating average gains of 105.0 per cent. in nitrogen and 75.9 per cent. in organic matter. The averages for the six dust samples show an increase of 95.4 per cent. in nitrogen and 72.6 per cent. in organic matter.

In the third section of Table XII is listed the average analyses of normal silt loam and dust samples as recorded by Fly (18). It will be observed that the average of fifteen dust samples indicates an increase of 115.0 per cent. in nitrogen and 76.8 per cent. in organic matter as compared to the normal soil. It will be seen then that the writer's results are almost identical to those obtained by Fly.

Another interesting feature observed from this table is that in every case, there is a greater increase or gain in the nitrogen content of the dust samples than in the organic matter. In other words, the wind apparently sifts out and

carries away the finer particles of organic matter which have a higher nitrogen content.

From these results it seems reasonable to conclude that the wind may very seriously impair the fertility of the soil by sifting out the more fertile portion (twice the normal), and carrying it away for hundreds of miles, an irreparable loss to the farmer and the nation as a whole.

Mechanical Analyses. In Table XIII is recorded the mechanical analyses of dust samples from Alberta and Oklahoma compared to soils "in situ". It should be noted here that the mechanical analyses of dust samples 134 and 135 was omitted only from insufficiency of samples for this purpose.

In examining the table, it is observed that in the silt loam samples and the fine sand samples, the average composition of the dust is very similar, the sand content being 29.8 per cent. and 25.7 per cent. respectively, the silt 58.5 per cent., and 63.9 per cent., and the clay 11.8 per cent. and 10.5 per cent. The soils "in situ" naturally vary tremendously as the one is a silt loam and the other a fine sand. This would lead one to believe that very similar wind sortation occurs on any type of soil.

In comparing the dust samples to the soils "in situ", it is seen that in the dust sample of the silt loam, there was a decrease in sand varying from 37.5 per cent. to 48.1 per cent. with an average of 42.7 per cent. The increases in silt

Table XIII. Mechanical analyses of dust from two points in Alberta and one in Oklahoma (by Fly), compared to soils "in situ"

Sample No.	Location	Sand %	Diff. %	Silt %	Diff. %	Clay %	Diff. %
	Silt Loam Soil (Barons)						
131	Normal	52.0	--	35.6	--	12.4	--
132	Acc. drift	64.2	+23.5	24.6	-30.9	11.2	- 9.5
133	Exp. sub.	50.5	- 2.8	34.7	- 2.5	14.8	+19.3
	Dust						
136	Dust - 25'	27.0	-48.1	58.6	+64.8	14.4	+16.2
137#	" 25'	32.5	-37.5	58.3	+63.8	9.2	-25.8
Average of dust		29.8	-42.7	58.5	+64.3	11.8	- 4.8
	Fine Sandy Soil (Carmangay)						
271	Normal	73.5	--	19.7	--	6.8	--
272	Acc. drift	85.8	+16.8	9.4	-52.3	4.8	-29.4
273	Exp. sub.	72.0	- 2.0	21.6	+ 9.5	6.4	- 5.8
	Dust						
274	Dust - 5'	18.0	-75.5	72.8	+269.6	9.2	+35.2
275	" 15'	25.0	-64.0	65.8	+234.0	9.2	+35.2
Average of dust		21.5	-70.7	69.3	+252.0	9.2	+35.2

Sample No.	Location	Sand %	Diff. %	Silt## %	Diff. %	Clay %	Diff. %
	Silt Loam Soil - Fly (Goodwell, Oklahoma)						
13	Normal	36.4	--	48.0	--	15.6	--
1	Acc. drift	58.2	+60.0	23.0	-52.1	18.8	+20.5
	Dust						
Average of dust (6)		14.3	-60.7	69.0	+43.8	16.7	+ 7.0

#Collected a year previously to the sample above.

##Percentages of silt and clay recalculated to conform to the new standards as used in own analyses.

varied from 63.8 per cent. to 64.8 per cent. averaging 64.3 per cent. In the clay content there was a loss in one case and an increase in the other, with a net loss of 4.8 per cent.

Considering the fine sands, it is observed that in the dust samples, an average loss in the sand content of 70.7 per cent. occurred. Though the actual silt content in this case is approximately the same as in the previous dust samples, the percentage increase is considerably higher, namely 252.0 per cent., on account of the low silt content of the normal fine sand. In regard to the clay, an increase of 35.2 per cent. occurred.

In examining the third section of Table XIII, it will be observed that in the dust from a silt loam area, Fly noted a loss of 60.7 per cent. in sand, a gain of 43.8 per cent. in silt, and a 7.0 per cent. increase in the clay fraction. In observing the averages obtained by the writer for the silt loam dust samples, it is noted that in both the actual content of the soil separates, and in the variation, the agreement is fairly close.

It therefore appears that the mechanical composition of dust is quite independent of the soils "in situ", being approximately 2/3 silt with minor amounts of sand and clay. The per cent. variation depends therefore on the normal soil to which it is compared.

Conclusions. In concluding this section on the

chemical and mechanical analyses of dust several important observations may be drawn.

(1) The varying degrees of loss in the fertility of wind eroded soils, as noted in an earlier section, are counterbalanced by the large increase in the chemical composition of dust as compared to the normal surface soils.

(2) The decrease in the silt content of wind accumulations, as also noted previously, is equalized by the high percentage of silt in dust samples.

(3) It also appears that the mechanical composition, though not the chemical analyses, of dust is quite constant, being independent to the soils "in situ".

(4) The very serious damage of wind erosion to the chemical and physical constitution of the soil, as further substantiated by the analyses of dust, makes it doubly important to control soil drifting.

GENERAL SUMMARY

A study has been made of winds and the effects of wind erosion on the composition and fertility of some Alberta soils. To observe these effects, a pot experiment was conducted, certain chemical analyses were carried out, and the mechanical analyses were completed on eighty one samples, collected from twenty seven locations in the province. A preliminary study

was also conducted of six samples of dust. A summary of the results of this investigation follows.

The survey of meteorological observations indicated that the wind in southern Alberta is double that in the central part of the province, and also is considerably higher than at two points in the "dust bowl" of the United States. It was further noted that in southern Alberta, 1/2 to 4/5 of the prevailing winds are from the west. The data also indicated that Lethbridge has twice the number of gales as Calgary or Medicine Hat.

In regard to the pot experiment, very material damage to soil fertility, as indicated by plant development, was noted on the fine sand. Only minor differences were observed on the silt loam and clay samples. No significant differences, however, were noted on the normal and eroded loam soil samples used.

The mechanical analyses indicated that with the coarse-textured soils, the greatest losses in silt and clay had occurred in the accumulated drifts, and there were also material decreases of silt in the exposed subsurfaces. In the medium-textured soils, significant losses in silt and clay were noted in the accumulations, but the exposed subsurfaces were substantially the same as the normal surfaces. Little difference was found in the fine-textured soils. Both the accumulated drifts and the exposed subsurfaces were similar to the normal soil, with a slight reduction in sand and an

increase in clay in each case.

The chemical analyses conducted on the samples indicated that with coarse-textured soils, very serious damage was caused by wind erosion. The fine-textured soils had suffered less severely, and the medium-textured soils indicated only a moderate loss of fertility.

The analyses of the dust samples indicated a very material increase in nitrogen and in organic matter, and also in the silt fraction, as compared to the normal surface soil.

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